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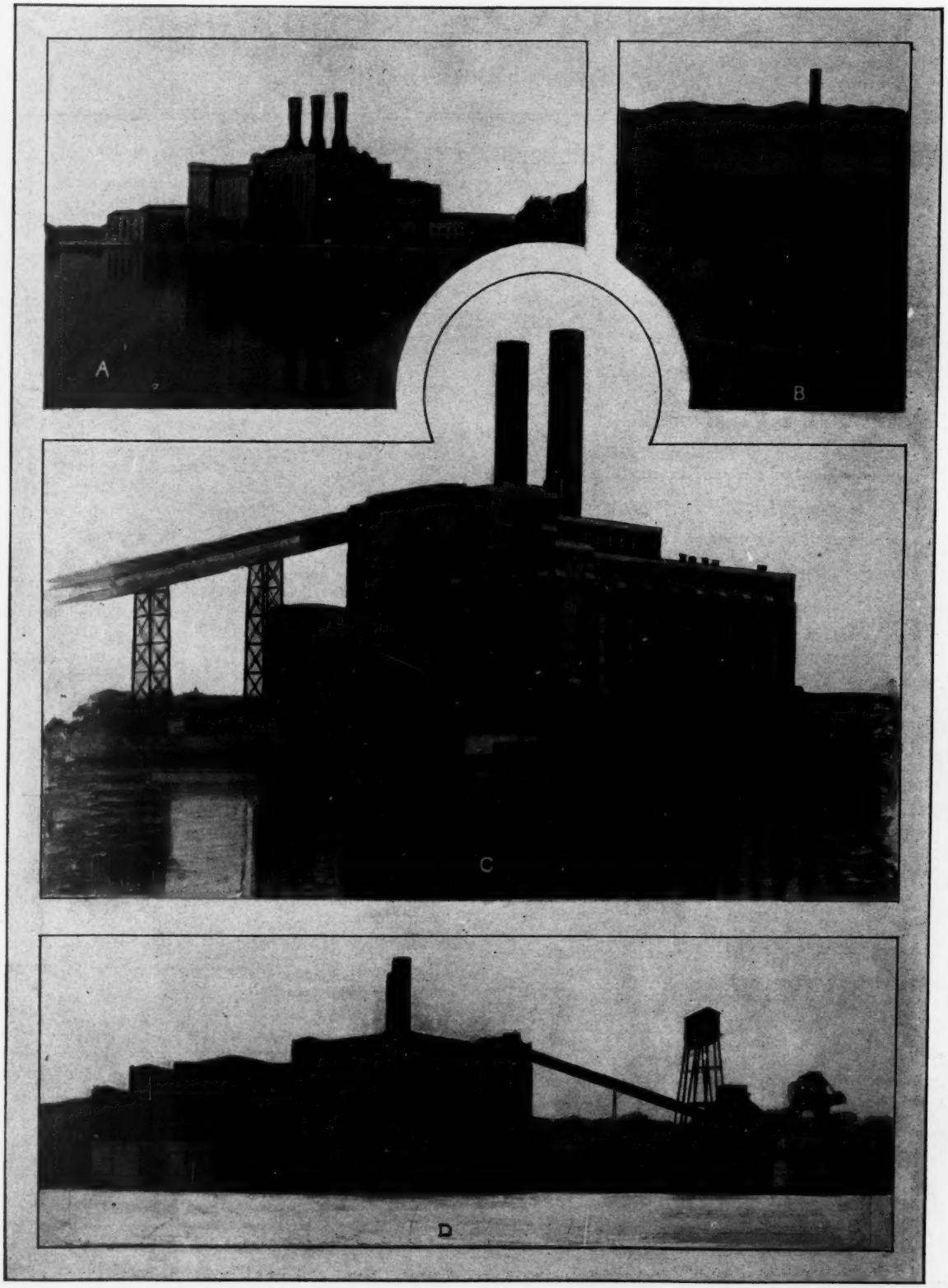
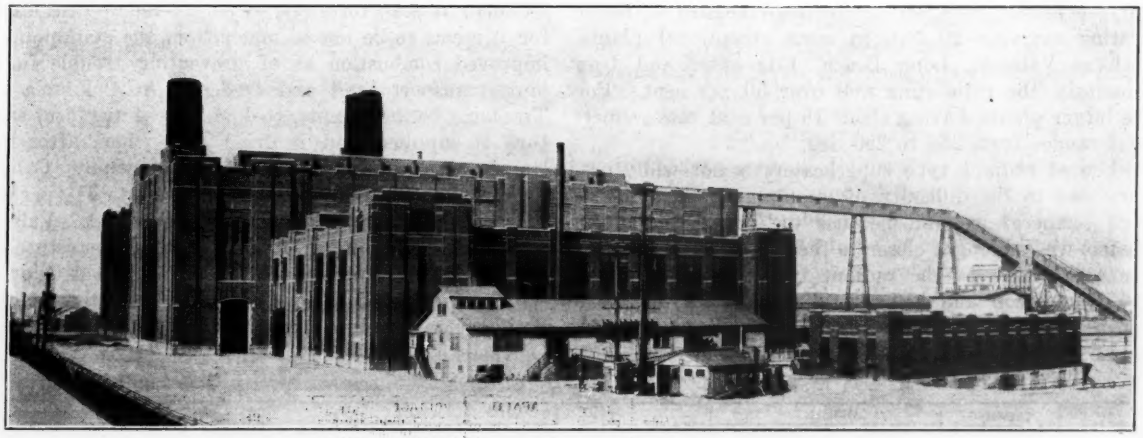
Typical American Power Stations



A. THE TRENTON CHANNEL PLANT, DETROIT, MICHIGAN. B. VALMONT STATION, DENVER, COLO. C. THE EDGAR STATION, BOSTON, MASS. D. COLUMBIA STATION, CINCINNATI, OHIO



Modern Power Plant Trends

EFFORT TO ACHIEVE THE GREATEST HEAT ECONOMY AND HEAT ADAPTATION TO CONDITIONS IS EVIDENT

CHOICE OF PLANTS for analysis to attempt to disclose modern tendencies in proportioning and equipment of power plants has been limited to an extent by data which could be procured as well as by time required for such analysis. It is believed, however, that sufficient typical plants, operating under various fuel and water conditions, have been included so that the best practice is well represented.

Features selected for consideration were those in which changes and progress have been most pronounced, including sizes of boilers, equipment with and arrangement of superheaters, economizers and air preheaters, furnace types and proportions, methods for insuring pure feed water, turbine size and arrangement, condenser practice and the main features of generation, transformation and switching of electric current.

As was to be expected, agreement in trends and divergence in detail methods are found but, in all features, effort to achieve the greatest heat economy and best adaption of equipment to operating conditions is evident.

BOILERS

Sizes above 25,000 sq. ft. of heating surface are not common, development tending rather to higher ratings, which, in some late plants, such as Trenton Channel, Kearny, Avon, Seal Beach and Fordson, reach 11 lb. evaporation per square foot of heating surface. The five plants mentioned represent four types of boiler so that, apparently, no one type is better adapted than another for large size and high rating.

One decided trend is toward using larger or more widely-spaced tubes directly over the fire so as to expose maximum surface to radiant heat. Another is to include the entire first bank or lower deck of tubes in the first pass, an arrangement which has helped in obtaining the higher ratings. It is notable also that superheaters are being located in the first pass for bent-tube boilers and, for latest straight-tube boilers, just above the bottom deck of tubes.

Pressures have increased but, although favorable reports come from the 1200-lb. installation at Edgar station and operation is satisfactory with 600 lb. at Columbia, Crawford and Philo plants, the majority favor 450 lb. until more definite experience is available as to upkeep and operation. Older central stations still use 300 lb. and industrial plants usually stop at 200 lb.

Apparently the number of passes in general use, which ranges from one to five, is more a function of external conditions and equipment than of the boiler itself. As feed water is brought more nearly to boiler temperature by extension of the regenerative cycle, the last passes, as well as economizers, become of less importance and responsibility for extracting heat from the flue gases is being thrown onto the air preheater. Reheating and extreme high pressure units have, so far, been of straight tube type but other types are being developed for such service. Reheat adds considerable complication to the piping layout for boilers and calls for automatic control of stokers according to the temperature of the reheated steam as well as automatic doors to admit cool air to the upper part of the setting, in case an accident interrupts the flow of steam. To protect from direct exposure to high furnace temperatures, reheat sections are placed above the regular boiler tubes and superheaters.

Mechanical soot blowers have become standard equipment, with compressed air used as a blowing medium in some high-pressure stations, although the majority of installations use low-pressure steam, taken from the auxiliary line or reduced through an orifice to the required pressure.

With one exception, Avon Station, where hand regulation of feed water is used because found satisfactory in other of the company's plants, feed water regulators are standard equipment.

SUPERHEATERS

Development has centered largely around the lowering of the elements so as to bring them closer to the fire. They are now located in the first pass of bent tube boilers, or just above the bottom deck for straight tube types. Little change is apparent in the percentage of superheating surface to boiler heating surface, although much steadier superheat is maintained with

varying loads. This per cent of superheating to boiler heating averages 20 but, in some exceptional plants, such as Valmont, Long Beach, Edgewater and Iron Mountain, the ratio runs well over 50 per cent. For the larger plants, having about 18 per cent ratio, superheat ranges from 250 to 280 deg.

Use of radiant type superheaters is not wide, possibly due to the difficulty of maintaining them in the high temperatures and because the convection superheater, when brought closer to the fire, gives practically the same effect as the radiant type. Riverside plant uses convection and radiant types in series to give a constant superheat at all loads, while the Fordson plant, although it was formerly so considered. Justification for it seems to be not so much from the standpoint of improved combustion as of preventing trouble in the bins, transport lines and feeders. At Columbia and Trenton Channel plants, coal of 3 or 4 per cent moisture is supplied and is dried only when, after long storage, it contains more than this amount. Cahokia dries coal from 11 per cent initial down to 8½ per cent and the mills further dry it to 5 per cent. Valmont uses lignite containing 19 to 28 per cent moisture but dries it all to 19 per cent in order to prevent bridging.

Experiences of various plants indicate that burners designed to produce turbulence of the coal and air

GENERAL DATA ON STATIONS

PLANT	DESIGNING ENGINEERS	COMPANY		LOCATION	TYPE PLANT	CAPACITY		VOLTAGE		STEAM PRESS.	FUEL	MAKE-UP	CONDENSING WATER
		HOLDING	OPERATING			PRESENT	ULTIMATE	GENERATED	TRANS-MISSION				
COLUMBIA	SARGENT & LUNDY INC.	COLUMBIA GAS AND ELECTRIC CO.	COLUMBIA POWER CO.	CINCINNATI O.	BASE LOAD	40,000	560,000	13,200	66,000	615	W. VIRGINIA COAL	OHIO RIVER	OHIO RIVER
CRAWFORD	SARGENT & LUNDY INC. & C.E. CO.	COMMONWEALTH EDISON CO.	COMMONWEALTH EDISON CO.	CHICAGO, ILL.	BASE LOAD	227,000	1,000,000	12,500	132,000	615	ILLINOIS	CHICAGO RIVER	CHICAGO RIVER
PHILO	SARGENT & LUNDY INC	AMER. GAS & ELEC. CO.	OHIO POWER CO.	PHILO, O.	BASE LOAD	80,000	240,000	11,000	132,000	615	BITUMINOUS	RIVER	MUSKINGUM R.
TRENTON CHANNEL	DETROIT EDISON CO.	THE DETROIT EDISON CO.		DETROIT MICH.	SYSTEM LOAD	200,000	300,000	12,200	120,000	430	W. VA. AND KENTUCKY	DETROIT RIVER	DETROIT RIVER
RICHMOND	STONE & WEBSTER & PHILADELPHIA ELEC. CO.	PHILADELPHIA ELEC. CO.	PHILADELPHIA ELEC. CO.	PHILADELPHIA PA.	SYSTEM LOAD	100,000	600,000	1400 DO	13,800 66,000	415	CLEARFIELD R.D.M.	DELAWARE RIVER	DELAWARE R.
KEARNY	PUB. SERV. PRODUCTION CO.	PUB. SERV. CO. OF N. J.	PUBLIC SERVICE ELECTRIC POWER CO.	KEARNY, N.J.	BASE LOAD	185,000	320,000	13,800	132,000	375	BITUMINOUS	RIVER	RIVER (HACKENSACK)
AVON	CLEV. ELEC. ILL. CO.	NORTH AMERICAN CO.	CLEV. ELEC. ILL. CO.	CLEVELAND, O	SYSTEM LOAD	70,000	300,000	13,200	132,000	405		LAKE	LAKE ERIE
SOMERSET	STONE AND WEBSTER INC.		MONTAUP ELECTRIC CO.	FALL RIVER, MASS.	BASE LOAD	60,000	210,000	14,000	66,000	390	OIL	COLES RIVER	TAUNTON RIVER
NARRAGANSET	JENKS & BALLOU	NARRAGANSETT ELEC. LTG. CO.		PROVIDENCE, R.I.	SYSTEM LOAD	35,000		11,000	66,000	390	NEW RIVER & POCAHONTAS	CITY	NARRAGANSETT BAY
EDGAR	STONE & WEBSTER, INC.	EDISON ELEC. ILLUMINATING CO. OF BOSTON		WEYMOUTH, MASS.	SYSTEM LOAD	67,150	350,000	14,000		375	NEW RIVER	CITY	FORE RIVER
LONG BEACH	STONE & WEBSTER, INC.	SO. CALIFORNIA EDISON COMPANY		LONG BEACH, CAL.	BASE LOAD	70,000	70,000	11,000	72,000	410	OIL & GAS	WELLS	PACIFIC OCEAN
SEAL BEACH	DWIGHT P. ROBINSON & CO.		LOS ANGELES G. & E. CO.	SEAL BEACH, CAL.	SYSTEM LOAD	36,000	180,000	13,200	110,000	400	OIL & GAS	CITY	PACIFIC OCEAN
SUSQUEHANNA	W.S. BARSTOW MANAGEMENT ASSN. INC.	GENERAL GAS AND ELECTRIC CO.	METROPOLITAN EDISON CO.	MIDDLETOWN, PA.	SYSTEM LOAD	65,000	200,000	13,200	66,000 & 114,000	365	MIXED BITUMINOUS & RIVER ANTHRACITE	WELLS	SUSQUEHANNA RIVER
CAHOKIA	MCCLELLAND & JUNKENFELD INC.	THE N. AMERICAN CO.	UNION ELECTRIC LIGHT AND POWER CO.	CAHOKIA, ILL.	SYSTEM LOAD	145,000	300,000	13,800	33,000	365	ILLINOIS	RIVER WATER	MISSISSIPPI RIVER
RIVERSIDE	UNITED L & P. ENG. & CONST. CO.	UNITED LIGHT & POWER CO.	RIVERSIDE POWER MFG. CO.	DAVENPORT, IA.	SYSTEM LOAD	20,000		13,200	66,000	440	CENT. ILLINOIS	WELL OR RIVER	MISSISSIPPI RIVER
WAUKEGAN	SARGENT & LUNDY INC.	PUBLIC SERVICE CO. OF NORTHERN ILL.		WAUKEGAN, ILL.	SYSTEM LOAD	60,000	250,000	12,500	132,000	400 LB.	ILLINOIS BITUMINOUS	LAKE MICHIGAN	LAKE MICHIGAN
VALMONT	HENRY L. DOHERTY & CO.	CITIES SERVICE CO.	PUB. SERVICE CO. OF COL.	DENVER, COL.	SYSTEM LOAD	20,000	200,000	13,600	100,000	390	COLO. LIGNITE	LAKE	VALMONT LAKE
HALES BAR	E.W. CLARK ENG. CO.	COMMONWEALTH POWER CORPORATION	TENN. ELECTRIC POWER CO.	CHATTANOOGA, TENN.	PARALLEL WITH HYDRO	40,000	40,000	13,200	125,000	390	TENN. BITUMINOUS	RIVER	TENNESSEE RIVER
BIG SIOUX	U. O. T. CONST. CO.		SIOUX CITY O. & E. CO.	SIOUX CITY, IA	SYSTEM LOAD	22,500	67,500	6,600	33,000	370	ILLINOIS & IOWA	WELL	BIG SIOUX RIVER
NEOSHO	KANSAS GAS & ELECT. CO.	AMER. PWR. & LTG. CO.	KANSAS GAS & ELECT. CO.	WICHITA, KAN.	SYSTEM LOAD	15,000		12,000	60,000 TO 132,000	365	KANSAS COAL, OIL AND GAS	NEOSHO RIVER	NEOSHO RIVER
DRESSER	STONE & WEBSTER, INC.	AMER. PUB. UTIL. CO.	INDIANA ELEC. CORP.	TERRA HAUTE, IND.	SYSTEM LOAD	60,000	60,000	13,200		365	INDIANA	RIVER	WABASH RIVER
EDGEWATER	HENRY L. DOHERTY & CO.	CITIES SERVICE CO.	OHIO PUB. SERVICE	LORAIN, OHIO	SYSTEM LOAD	25,000		6,600	132,000	315	E. OHIO BITUMINOUS	LAKE	LAKE ERIE
BARBADOES	U. G. I. CONT. CO.	UNITED GAS IMP. CO.	COUNTIES GAS & ELECT. CO.	MORRISTOWN, PA.	SYSTEM LOAD	40,000	120,000	13,000		320	BITUMINOUS	RIVER	SCHUYLKILL RIVER
PINE GROVE	J.G. WHITE ENG. CORP.	EAST PENN. ELEC. CO.	LEHIGH POWER SEC. CORP.	PINE GROVE, PA.	SYSTEM LOAD	25,000	200,000	12,000	66,000	315	ANTHRACITE	RIVER	SPRAY POND
IRON MT.	ALBERT KAHN, INC.	FORD MOTOR CO.	FORD MOTOR CO.	IRON MT. MICH.	INDUSTRIAL	9,500	10,000	13,200 4600	13,200	265	INDUSTRIAL WASTE	MENOMINEE RIVER	NON COND.
FORDSON	ALBERT KAHN, INC.	FORD MOTOR CO.	FORD MOTOR CO.	DETROIT, MICH.	INDUSTRIAL	115,000	240,000	13,200	13,200	265	KENTUCKY & W. VA.	CITY WATER	RIVER ROUGE
BROTHERHOOD OF L.E. BLD.		BROTHERHOOD OF LOCOMOTIVE ENGINEERS		CLEVELAND, O.	OFFICE BLDG.	2000	2000	250	250	235	BITUMINOUS	CITY WATER	NON COND.
BETTENDORF	BETTENDORF CO.	BETTENDORF COMPANY		BETTENDORF, IA.	INDUSTRIAL	5000	7500	2300	115-230 460	165	WASTE HEAT AND OIL	RIVER WATER	MISS. RIVER
BAYONNE	STANDARD OIL CO	STANDARD OIL CO.	STANDARD OIL CO.	BAYONNE, N.J.	INDUSTRIAL	NO ELECTRICAL EQUIPMENT				195	ANTHRACITE	CITY	NON. COND

which uses the water screen as independent of the boiler, carries the steam so generated through a radiant superheater direct to the steam main. This superheater is protected somewhat from intense heat by installing it behind a water screen formed by cutting the fins from the fin-tube side walls.

Total temperature ranges about 750 deg. as the maximum practical limit. Higher temperatures are reported in Europe but, with present metals, it is felt that the risk involved, considering the temperature and mechanical stresses in large units, is not justified.

Pulverized Fuel Practice

Most of the plants tabulated use the bin or central system, thus seeming to establish it as general practice for large central stations, but unit pulverizers have been applied successfully, especially in the rebuilding of boilers and furnaces. Sherman Creek, Brunot Island, Rochester Gas & Electric Co., and Mahoningside have all reported good results with the unit system. Drying does not seem to be always necessary, stream, or to give whirling flame in the furnace, offer possibilities for economy. Trenton Channel has made experiments with modified forms of the fan tail burner, with deflectors and steam injection. Several new types of burners designed to produce turbulence are now on the market. The horizontal and vertical arrangement at the Columbia station has given good results. The Sherman Creek plant is using well-type furnaces and one has been installed at Brunot Island but no results have, as yet, been reported. Buffalo General Electric Co. is now installing a modified well-type furnace under four new boilers.

As to furnace walls for pulverized fuel furnaces, the plants tabulated do not show a majority using water-cooled walls but do show a tendency in that direction. If some other plants such as Colfax, Brunot Island, Sherman Creek and Hell Gate had been included, the tabulation would have a decided leaning toward use of fin-tube walls or water-cooled refractories. Columbia, Avon and Trenton Channel use air-cooled

walls successfully and the Cahokia plant, which has used air-cooled walls, is changing to water-cooled.

Stokers

For plants of large size, apparently only two types of stokers are considered. These are the underfeed and the forced draft chain grate, the underfeed prevailing in plants burning bituminous coals, while the chain grate is chosen in most cases where anthracite or middle west bituminous coals are burned. Gradual increase in furnace volume has been taking place over 20 yr. until, today, the peak seems to have been definitely reached and, because of the use of preheated air and agitation of the furnace gases, material reduction in furnace volume is predicted by combustion authorities.

Artificially-cooled furnace walls are coming into use, either air-cooled with tile corbelling, or water-cooled, or in some cases the use of radiant-type superheaters.

PHILO STATION OF THE AMERICAN GAS & ELECTRIC CO., AT PHILO, OHIO

All these tend to reduce furnace temperatures with beneficial effect on the life of the refractory.

Economizers and Air Preheating

Increase in boiler pressures has brought about changes in the economizer. Steel tubes with protected gas surfaces are now commonly used, the integral type being usually favored rather than the group arrangement. In fact, it is the tendency to make each boiler unit independent, with the units interconnected only through feedwater and steam mains. With high-pressure boilers, the tendency is to use a higher ratio of economizer surface to boiler heating surface than was formerly practiced, the counter flow arrangement possible with economizers giving a more efficient heat transfer.

Use of air preheaters depends on how they fit in with the extraction feed water heating arrangement; also, where air preheaters are used, it has an effect on the amount of economizer surface installed per boiler but no definite relation has yet been established, as the most desirable degree of preheating is still an unsolved problem. Columbia with pulverized coal and Philo with stoker firing both use preheaters and economizers, while the Fordson plant uses a large preheater and no economizers and Avon, the newest pulverized coal plant, has no air preheaters.

Draft Practice

In modern central stations the practice is tending more and more to the use of both forced and induced draft, since boilers and furnaces have grown to such proportions and are operated at such high ratings that this equipment has become necessary. Fans vary in capacity between 20,000 and 280,000 cu. ft. a minute, with motors used almost exclusively for drive. The variable speed, a.c. motor is most popular, one fan per boiler being used on both the forced and induced draft sides.

Feed Water Systems

Proper treatment of feed water to prevent scale formation and corrosion becomes more essential as pressures and temperatures in the boilers increase. While no radically new developments in methods of treatment have appeared, many old methods have developed to adapt them to modern conditions. Most widely used of the chemical methods are the lime-soda, hot process and the zeolite process. Tri-sodium phosphate as a substitute for sodium carbonate in water treatment is also advocated.

Use of evaporators for distillation of feed water is increasing and all of the larger stations use some method of deaeration, which is often combined with one stage of the regenerative cycle of preheating that has now become standard for all large stations.

Steam Turbines

Development to operate with pressures of 500 to 600 lb. and temperatures of 700 to 750 deg. has taken place, with the Edgar plant specially operating at 1200 lb. Reheating of steam is practiced at Columbia, Philo, Crawford and Edgar plants, the reheating at Columbia being after passage through the high-pressure cylinder of the tandem-compound unit, at Philo between the seventh and eighth stages, at Crawford de-

SEAL BEACH STATION, SEAL BEACH, CAL.

pending on the design of the units but being at pressures of 110 to 132 lb. and at Edgar after exhaust from the 1200-lb. turbine. No reheat will be used in the No. 4 Crawford unit.

Tandem-compound arrangement of units is used at Columbia and Richmond and cross-compound at Crawford but most other large turbines are of single-cylinder type.

Much consideration has been given to the special design of blading for the low-pressure end, where difficulty is encountered in passing the large volume of steam through the blades without making them of undesirable length. Compounding is, of course, one answer to this problem and another has been the splitting of the steam in the last two or three stages among two or more sets of blades. Bleeding of steam for process work and for the stage heating of feed water has become standard practice, three or four stages being ordinarily used, although the Avon station has only one stage.

A development having promise in the direction of heat economy would be the increase of initial temperature, but the problem of development in materials has held this back.

Condensers

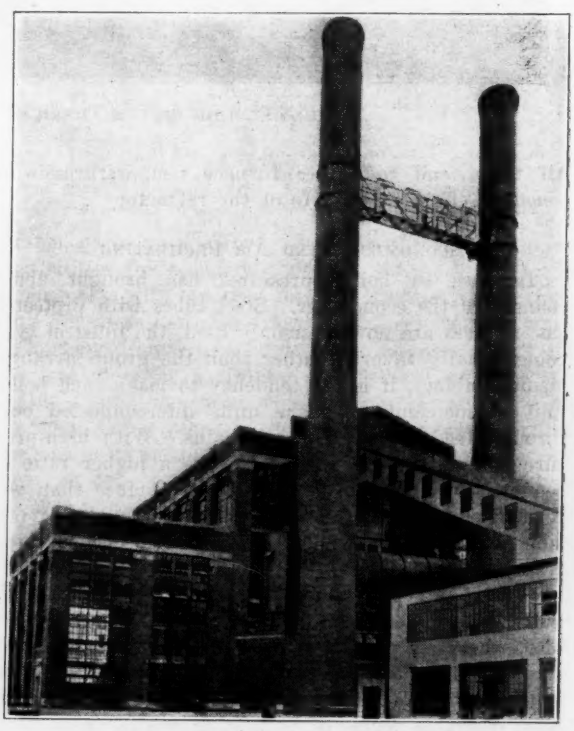
For conditions where water level fluctuations are great, or where excavation cost for horizontal condensers would be prohibitive because of the large size of the unit, the vertical condenser is admirably adapted, as typified in the plants at Columbia, Philo and Crawford. By splitting units into two sections, as at Crawford, the piping for the turbine exhaust and the general auxiliary layout are greatly simplified, while manufacturing and installation problems become those of a unit of half the size otherwise required.

Where water is plentiful, the single pass condenser is becoming a favorite, Susquehanna, Avon, and Trenton Channel being recent examples of this practice. Tendency is toward the use of smaller surfaces per installed kilowatt of capacity even where the single pass is not adopted. Surfaces of considerably below 1 sq. ft. per kw. are not uncommon, although the larger stations are more conservative and it is probable that the value of 0.95 at Trenton Channel will be the record for some time.

Low condensate temperature, which was characteristic of the older designs and of the vertical types because of the arrangement of the lower tube sheet of this type, is of small consequence in plants where steam is bled from the lower stages of the turbine but can be remedied easily by the reheating hotwell.

Examples of small surfaces per kilowatt for other than single pass condensers are the two-pass units at Columbia, Richmond, Kearny, Susquehanna and the second Valmont unit. Older stations in the Mississippi Valley, such as Barbardoes Island, Pine Grove, Neosho, Dresser and Hales Bar, use considerably larger surfaces, due perhaps to water conditions but, where changes have taken place in the same plant between new and old units, as in Cahokia, Fordson and Valmont, decreased temperatures and increased steam flow per unit surface are evident. Fordson is the only plant considered which uses three-pass units, while at Narragansett, because of the corrosive water, the jet type was adopted with lead-lined shell. This is the largest jet condenser ever built and consists of two units operating in parallel.

For tubes, Muntz and Admiralty metals continue to hold first place, although brass has been used at the plants of the Bettendorf Axle Co., at Edgewater, Valmont and Waukegan stations, four plants in widely



THE IRON MOUNTAIN PLANT OF THE FORD MOTOR CO.

separated parts of the country. One inch tube of No. 18 B.w.g. are nearly standard, although the 16 gage is found more economical in some plants because of longer life, notably in the Pacific Ocean plants at Long Beach and Seal Beach, which use sea water uncontaminated by sewerage. For the packing of tubes, perhaps the most common practice is rolling or expanding one end of the tube into the tube sheet and using a standard packing of some form on the other end.

Deaeration in hotwells is making progress because of its efficiency in oxygen removal and, in many cases, has eliminated the necessity for deaerators in the system. At Riverside and Big Sioux plants, feed make-up is introduced into the condenser, and carried along with the condensate.

Variable speed circulation pump motors are used in most stations with a tendency toward the use of two pumps, both with and without a divided water box.

For air removal, steam jet ejectors are the favorite method but often installed in parallel with rotary dry vacuum pump. Trenton Channel, Edgar and Cahokia plants still use only the rotary dry vacuum pump and it is possible that, with the development of the vertical type of this pump, it will again come into favor because of its lower power consumption.

Generators

Electric generator design has undergone no radical changes during the past few years except that size of units is steadily increasing. Apparently there is no difficulty in building generators to connect up to any size turbine that may be designed.

Voltage is standard around 12,000 to 13,000 v. with 6600 v. used in smaller installations but the smaller voltage is the exception. Universal use of 60-cycle frequency limits the speed of generators to either 1200 or 1800 r.p.m. Because of its many advantages, use of the shaft generator for auxiliary supply is becoming popular. The house turbo-alternator is also used, but because of relatively low efficiency is mainly for emergency use, normal auxiliary supply being derived from the main alternating current system through transformers.

Noteworthy advances have been made in cooler design and cooling methods, among them being the use of washed air for generator cooling and the incorporation of fire protective and detection methods which have arrived at an efficient and reliable status.

Generator leads in most cases are connected directly to low-voltage buses through main circuit breakers but, in several recent installations, generators are connected direct to the primary windings of step-up transformers and all switching is done on the high tension side of the transformer. Widely different designs of switching equipment are used in different stations but, in all cases, remote control is used from the main control room. Hydraulically operated switch gear, which is installed in a number of recent stations, seems to be giving good satisfaction. Grounding of the neutral is quite general and, to guard against internal trouble, differential relay protection is used in nearly all cases. In a few cases reactors are placed in the generator leads to limit the current under short circuit conditions but the practice is not general.

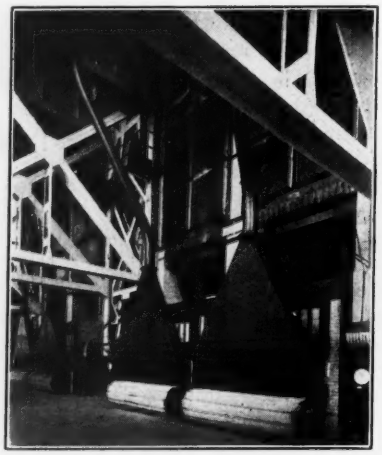
Electrical Switching and Transformation

Use of the isolated phase arrangement of busses with interlocks on circuit breakers and also disconnects and compartment doors are important developments in the switching system. Switching on the high-voltage side of transformers has already been mentioned. Protection of switching devices and systems is the important development in the feeder system control, with greater use and development of lightning arresters and surge absorbers.

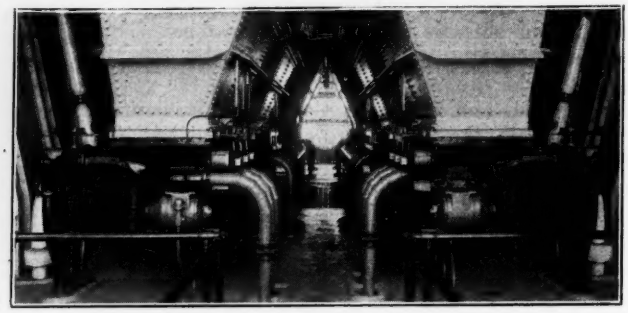
In transformer practice, the most noteworthy steps are the interlocking of circuit breakers and the location of taps in the middle of windings. Cooling methods have also been developed, water cooling being used to an increasing extent.

In general, the development of station practice may be defined as working toward the greatest possible heat economy, maximum safety for machinery and operators, centralization of control of apparatus and the simplification of control methods and of operating routine.

AN AIRPLANE VIEW OF RICHMOND STATION AT PHILADELPHIA, PA.



Combustion Progress



OUTSTANDING CHANGES RESULT FROM ADAPTATION OF PULVERIZED FUEL, ARTIFICIALLY COOLED FURNACE WALLS AND REGENERATIVE HEATING. BY C. F. HIRSHFELD*

IT IS EXCEEDINGLY wise for those immersed in a major development to step out of the picture occasionally and to attempt to appraise the progress made as it would be viewed by an outsider. Only in this way is it ordinarily possible to obtain correctly proportioned estimates of real values. With such estimates in mind one may return to his task with a better perspective and with greater certainty of accomplishing quickly the next logical steps.

Development of combustion methods and equipment has been so exceedingly rapid during the past few years that it seems particularly pertinent now to stop long enough to look hastily over what has been done and what appears to be in the doing.

It may be said that three different things occurring almost concurrently have been largely responsible for the exceedingly rapid recent development in this field. These are:

(a) The final adaptation of pulverized fuel to use in steam boiler furnaces.

(b) The adaptation of the artificially cooled furnace wall to stationary boilers of the water tube type, and

(c) The rapid and extensive adoption of regenerative heating in steam power plants.

Adaptation of pulverized fuel not only set new standards of thermal performance but also new standards of furnace size, new conceptions with respect to attainable flexibility and new ideas with respect to the availability of the poorer grades of coal. It is not necessary to argue here the question of net results obtained by the use of pulverized fuel; the fact of importance now is that its use brought about in a short period of time very great changes in what the combustion engineer thought it reasonable to demand of combustion equipment and reasonable to provide in order that combustion equipment might function to the best advantage. Higher thermal efficiency, greater flexibility, greater ease of control, greater freedom from limitations previously set by small variations in character of coal, all came into the picture suddenly and served to jar loose previously existing habits of mind. Complications previously undreamt of in the minds of practical operators were accepted; furnace sizes far exceeding anything previously considered as normal were approved.

The introduction of the artificially cooled furnace wall in one form was a direct result of the use of pulverized fuel but the water cooled furnace wall followed immediately after and appears to have been first applied to stokers. In fact both air cooling and water cooling had for years been applied to small sections of the walls of stoker fired furnaces. The real development came with an appreciation of the fact that such cooling could be applied on a much greater scale than had been realized. The introduction of such extensive cooling made possible an immediate increase in the output of a furnace of a given size and therefore raised materially the ratings obtainable from boilers set over furnaces of given dimensions.

Introduction of regenerative heating brought about a situation in which the economizer could no longer be used advantageously to the same extent as before. High economy in the turbine room required heating the feed water to a high temperature by means of bled steam and this was not consistent with high economy obtained in the boiler room by means of economizers. The result was the adoption of the air preheater, either alone or in combination with a comparatively small economizer. The air preheater was found greatly to improve combustion, shortening the flame, making combustion more complete and control more flexible.

Manufacturers of stokers may not have believed all of the claims made for pulverized fuel but they were not long in realizing that improvements in stokers were in order. Such improvements were made rapidly and effectively in both the chain grate and underfeed types. With the larger furnace sizes that were being used,

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with the acceptance of greater complication and with the introduction of preheated air and water cooled or air cooled walls it became possible for the stoker manufacturer to obtain results previously impossible. In a general way it may be said that stokers have been greatly increased in size, have been made more flexible both with respect to control and to variations in character of fuel and have been improved with respect to extent and cost of maintenance required.

At the present time it is possible to equip a boiler plant with either stokers or pulverized fuel firing equipment capable of driving the boilers at what would have been considered exceptionally high ratings a few years ago. There are authentic records of pulverized fuel operation at over 400 per cent boiler rating for long periods of time and of stoker operation at over 500 per cent boiler rating. There is reason to believe that both figures can be materially exceeded if it is found desirable to do so. Moreover, equipment of both kinds is capable of giving gross thermal efficiencies of between 85 per cent and 90 per cent over fairly wide ranges of load.

It looks as if we have about reached the maximum development of furnace size for some time to come. At present, effort is being concentrated on burning more fuel in furnaces of the present size rather than going further in increasing furnace dimensions. In the case of stokers this is being brought about largely by the use of well cooled furnace walls and the use of highly preheated air, combined with improvements in stoker design directed toward eliminating clinkering difficulties. In the case of pulverized fuel it is being accomplished by the use of well cooled furnace walls, preheated air and turbulent types of burners intended to give shorter flames due to more perfect mixing of fuel and air.

It is interesting to note that the use of turbulent types of burners which is now made possible by improved furnace construction is a reversion to the earlier methods suggested but which were found impracticable because the furnace walls in use at that time could not withstand the combined action of ash and high temperature and because no means were available for preventing the fusion of ash into a mass at the bottom of the furnace.

In the case of pulverized fuel, the evidence at hand points to a continued development and ever increasing use of the unit mill idea and the abandonment for most purposes of the central preparation type of plant. It is as yet too early to state positively that it will be possible to handle all types of fuel on the unit principle and there is still some question with respect to the degree of flexibility and accuracy of control. Such evidence as is available points however to the ultimate adoption of the unit principle.

In the case of stokers it appears that increasing size, adaptation to very highly preheated air, and better control of fuel and air are to be expected.

Progress in the Burning of Pulverized Coal

DISCUSSION OF TYPES OF FURNACES USED, PREPARATION AND BURNING OF COAL, USE OF AIR PREHEATERS AND VARIOUS OPERATING EXPERIENCES

IN THIS ANALYSIS of the developments in the burning of pulverized coal during the past two years, it should be kept in mind that we expect to treat here only those developments that have been in regular operation. The developments noted here have, as might be expected, led to further changes and at present designs are being installed which carry these developments to their logical conclusions.

There has been a decided trend toward the use of water-cooled furnace walls and elimination of refractories. From this has developed the well-type furnace and the steam generator in which the furnace walls generate all the steam.

In the stations which will be analyzed here it will be noted that the central or bin system of pulverized coal preparation is used almost exclusively, typified by Fig. 1. At several stations, however, experiments have been carried out with many types of unit pulverizers and it appears that the unit system is being given much consideration. This is particularly true in cases where boiler plants have been rebuilt; in such cases the unit system has been found to be one solution of the problem.

GENERAL COMMENTS ON BURNING PULVERIZED COAL

In many cases it is found that the coal burned in pulverized coal plants at present is that which can be delivered to the plant at the lowest cost per B.t.u. rather than the lowest cost per ton. It will be noted also that some stations are burning coal in pulverized form which probably could not be burned economically by other methods. At the Binghamton and Susquehanna stations, anthracite has been burned with considerable success although boiler ratings and efficiencies are not as high as can be obtained with bituminous coal. As noted on Table I, the Valmont plant burns Colorado lignite with a moisture content running as high as 28 or 30 per cent but averaging about 22. Several plants in Texas which are not tabulated here are also burning lignite.

Some stations, such as Valmont, have found it necessary to dry the coal before pulverizing in order to

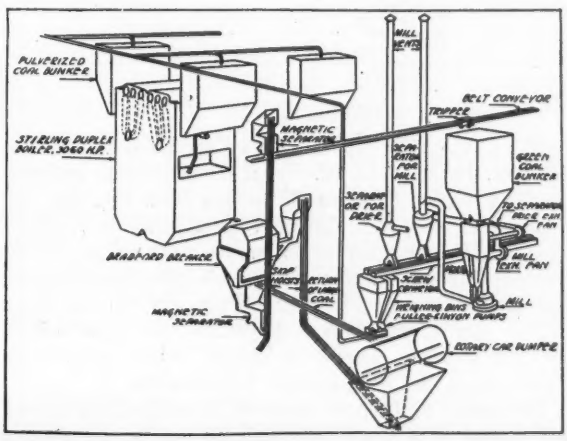


FIG. 1. COAL PREPARATION PLANT AT AVON STATION

prevent bridging in the bunkers and trouble with the pulverized coal feeders. Some drying of the coal is, of course, effected by admitting warm air to the pulverized coal circulating system. In general, however, there seems to be a tendency to get away from the use of dryers as much as possible. At the Trenton Channel plant, for instance, they are installed primarily for emergencies in handling coal which may have absorbed excessive amounts of moisture from being stored for long periods.

Elimination of dust, both coal and ash, is being given considerable attention in pulverized coal plants. According to the 1926 report of the Pulverized Fuel Committee of the N. E. L. A., recent developments indicate that 95 per cent or more of the ash from flue gas can be removed by the electrical precipitation method. Considerable experimentation has been carried on at the Trenton Channel station with such precipitators and some interesting results may be expected in the near future. Cindervane fans and special types of collectors are used in some cases with success, while spray type washers have also been applied to this work.

The range of furnace volumes in modern pulverized fuel plants is between 0.35 and 1.0 cu. ft. per square foot of boiler heating surface, with a tendency in the newer installations toward the lower rather than the upper limit. In the plants tabulated here it will be noticed that the average is about 0.6 or 0.7. Water cooling of furnace walls, however, and means for increasing the turbulence of the coal and air mixture as it is injected into the furnace will have considerable effect in keeping these furnace volumes down. Several types of burners for increasing turbulence have been recently developed.

Installation of pulverized coal burning equipment which will be completed in the near future will illustrate the general tendency noted here. At one of these, a large central station, boilers equipped with well type furnaces are being installed. Some time ago an experimental furnace was installed at this plant in which extremely high combustion rates were attained. The results were so good that, with some modifications, the same type of furnace has been applied to four new boilers now being installed at this plant. The experience with well type furnaces at Sherman Creek has also proved most instructive. One boiler was originally provided with well type burners located outside the furnace proper and arranged so that the turbulent action would be produced in the wells or boxes. After some experimenting with this construction it was finally

COAL PULVERIZING EQUIPMENT

PLANT	COAL		DRYERS			PULVERIZING MILLS				COAL TRANSPORTATION SYSTEM	TYPE FEEDERS	SYSTEM
	KIND	B.T.U. PER LB.	TYPE	INITIAL MOISTURE IN COAL	FINAL MOISTURE AS FIRED	TYPE	CAPACITY	POWER CONSUMED	FINENESS OF PULVERIZING			
COLUMBIA	W. VA.	14,040	ROTARY-PULV. COAL FIRED	3%		SCREEN TYPE	6½ TON	12 KW. HR. PER TON	60-70% THRU 200 MESH	SCREW PUMPS-AERATED	TRIPLEX	CENTRAL
CRAWFORD						STOKERS						
PHILO						STOKERS						
TRENTON CHANNEL	W. VA. & KY.	13,600	GRID STEAM FOR EMERGENCY & AIR	4% AVE.	0.3 TO 1.3	ROLLER IMPACT	6 TON	AVE. COST OF PULV. 25.35¢	65% THRU 200 MESH	SCREW PUMPS-AERATED	DUPLEX	CENTRAL
RICHMOND						STOKERS						
KEARNY						STOKERS						
AVON			GRID STEAM AND AIR			6 ROLLER IMPACT	15 TON		65% THRU 200 MESH			
SOMERSET						FUEL OIL						
NARRAGANSET	NEW RIVER & POC. SLACK		GRID STEAM AND AIR			ROLLER IMPACT	15 TON			SCREW CONVEYORS AND SCREW PUMP	METERING AND DUPLEX	
EDGAR						STOKERS						
LONG BEACH					OIL	AND GAS						
SEAL BEACH						OIL						
SUSQUEHANNA	MIXED ANTHR. AND BIT. FROM RIVER	11,900 TO 14,000	STEAM AND FLUE GAS			2 ROLLER IMPACT 2 SCREEN TYPE 1 BALL	6 TON	15-17.90 KW. HR. PER TON		SCREW PUMPS AERATED	TRIPLEX	CENTRAL
CAHOKIA	BELLEVILLE KATHLEEN SCREENINGS	9,7000 10,600	FLUE GAS	11.0	DRIERS TO 8.5 MILLS TO 5	12 ROLLER IMPACT 1 SCREEN TYPE	6-6T.-4-1ST. 20T.	12.5-15 KW. HR. PER TON		COMPAIR TANK SYSTEM SCREW PUMP ON 20T. MILL	10 FEEDERS FROM 1 MOTOR	CENTRAL
RIVERSIDE						STOKERS						
WAUKEGAN						STOKERS						
VALMONT	COLORADO LIGNITE	6892 TO 9872	FLUE GAS	19.25 26.79	19	ROLLER IMPACT	6 TON	14-18 KW. HR. PER TON		SCREW CONVEYORS	DUPLEX	CENTRAL
HALESBAR						STOKERS						
BIG SIOUX	IOWA	8870	FLUE GAS OR STEAM			ROLLER IMPACT	6 TON	18-21 KW. HR. PER TON		SCREW PUMPS AERATED	7 FEEDERS FROM 1 MOTOR	CENTRAL
NEOSHO						STOKERS						
DRESSER						STOKERS						
EDGEWATER						STOKERS						
BARBADOES						STOKERS						
PINE GROVE						STOKERS						
IRON MT.		NINE	DIFFERENT	FUELS		IN SUSPENSION - SEE TEXT						
FORDSON	B.F. GAS KY. COAL	100 B.T.U./CU. FT. AT 300 DEG. 13,500-14,200	AIR DRIED IN MILL	3		6 ROLLER LOW SIDE IMPACT	6 TON & 15 TON		78% 200 MESH 99% 100 MESH	SCREW CONVEYORS	SIMPLEX	CENTRAL
BROTHERHOOD OF L.E. BLDG.						STOKERS						
BETTENDORF					WASTE HEAT							
BAYONNE						STOKERS						

decided to introduce the burners into the furnace in such a way as to set up turbulent action inside the entire furnace. This arrangement is shown in Fig. 2.

Many Types of Coal Have Been Pulverized

As noted above, many kinds of coal have been successfully burned in pulverized form. These coals range from West Virginia and Kentucky coals of 13,000 and 14,000 B.t.u., as burned at Columbia and Trenton Channel, down to the Iowa coal of 8870 B.t.u. burned at the Big Sioux station, and the Colorado lignite burned at Valmont. At Narragansett plant it was found that New River and Pocahontas slack gave the lowest cost, greatest availability and a high B.t.u. content. At the Susquehanna River station mixed anthracite and bituminous dredged from the river are burned with extremely good results. At the Fordson or River Rouge plant a good grade of Kentucky coal is burned in combination with blast furnace gas from the industrial processes.

Most of these stations use stationary dryers employing steam and air, steam and flue gas, or flue gas alone as the drying medium. At Columbia rotary dryers are used, the drying medium being flue gas from a pulverized coal burner. The Fordson plant has no dryers installed, as the coal is air dried in the mill.

One Plant Burns Nine Fuels in Suspension

Of particular interest in discussing fuels is the arrangement used at the Iron Mountain plant. Here nine different fuels are burned in suspension in a standard type of pulverized coal furnace with air-cooled hollow walls. Pulverized coal in this case forms only a small portion of the fuel burned. Almost 100 per cent of the fuel burned at Iron Mountain consists of industrial by-products from a large chemical plant and wood-working factory. Dry chips, shavings and dry sawdust are produced in a large body plant and these three fuels are burned in suspension. Wet sawdust and hogged fuel are produced in the sawmill and, if not used in the chemical plant, can be burned on grates at the bottom of these furnaces. The chemical plant, which takes most of the wood waste from the wood-working processes, supplies wood gas, oil and tar as well as charcoal to the plant as by-products of the wood distillation process which it carries on. The gas is piped direct to the furnaces, the oil and tar are handled by standard oil burning equipment and the charcoal is pulverized and handled with pulverized coal equipment. To supplement this arrangement, pulverized coal was added since the chemical plant by-products are not always sufficient.

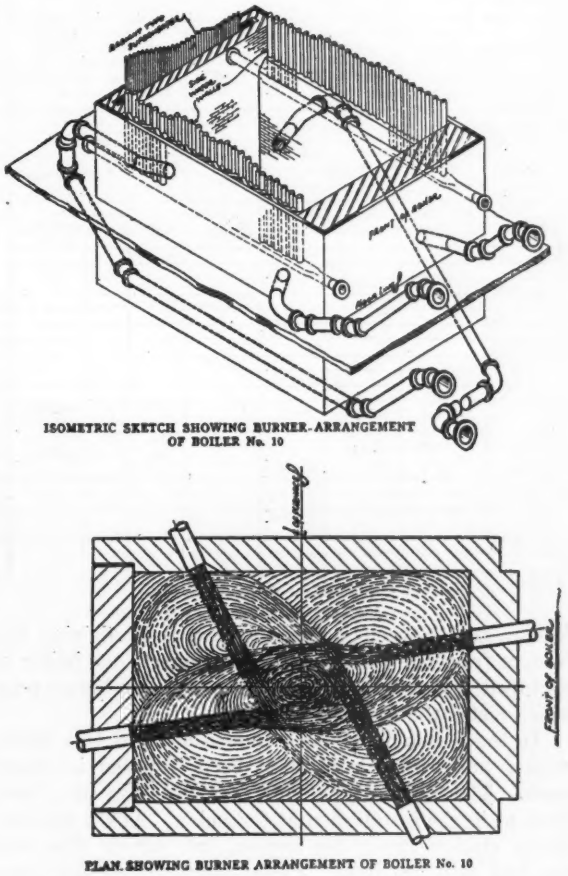
At the plant of the Bettendorf Co., steam is generated in the boilers by waste heat from basic open hearth furnaces as noted in the tables.

In plants like Columbia and Trenton Channel where the coal has an initial moisture of 3 or 4 per cent the drying of coal is not always necessary, as noted, except in cases of emergency. At Cahokia, however, the coal, which is Belleville and Kathleen screenings, has an initial moisture content as high as 11 per cent. The dryers, which are of the flue gas type, reduce this moisture to 8.5 per cent and it is further reduced to 5 per cent in the pulverizing mills. At Valmont, burning lignite having a moisture content of anywhere from 19 to 28 per cent, it is found that as far as combustion is concerned this lignite can be burned without drying. Some trouble, however, is encountered with bridging in the bins when the moisture content is above 19 per cent, so it is usually dried to this point. In addition it is found that drying increases the capacity of the mills from their nominal rating of 6 t. to about 10 t.

In general the coal is pulverized for use in these plants so that about 65 per cent of it passes through a 200-mesh screen. The figure given for the Fordson plant is 78 per cent but, as far as we can determine, from 60 to 70 per cent is a common figure.

Transporting Pulverized Coal

Transportation of pulverized coal from the mills to the boilers, in the case of the plants tabulated here, is



ISOMETRIC SKETCH SHOWING BURNER ARRANGEMENT OF BOILER No. 10

PLAN SHOWING BURNER ARRANGEMENT OF BOILER No. 10

FIG. 2. BURNER ARRANGEMENT TO PRODUCE TURBULENCE IN A FURNACE AT SHERMAN CREEK

usually by means of screw pumps with air introduced to aerate the coal and make it flow easily. At Narragansett screw conveyors are used in some parts of the system and Valmont plant uses them entirely. At Cahokia, one of the pulverizing mills is a 20-t. screen type mill and in connection with this mill a screw pump is used for transportation. For the rest of the Cahokia system, however, which includes 12 roller impact mills, the compressed air tank system is used.

Feeders for pulverized coal are usually duplex or triplex for the larger stations and this arrangement has been carried further at Big Sioux by driving seven

PULVERIZED COAL FURNACES

PLANT	BOILER HEATING SURF. SQ. FT.	FURNACE VOLUME CU. FT.	FURNACE CU. FT. PER SQ. FT. B.H.S.	HEAT LIBERATED B.T.U. PER CU. FT. AVER.	PERCENT BOILER RATING	BURNERS NO. PER BOILER	BURNERS TYPE	TYPE FURNACE WALLS	WATER SCREENS CONNECTION	WATER SCREENS HEATING SURF. SQ. FT.	ASH DISPOSAL ASH FROM FLUE GAS	ASH DISPOSAL HOPPERS	ASH DISPOSAL TRANSPORTING
COLUMBIA	15,110	12,568 7110	0.83 0.47—	CYLINDRICAL	FURN.	15	9 VERTICAL 6 HORIZON.	AIR COOLED SECTIONAL	NONE INSTALLED			AIR COOLED	CONTINUOUS ASH SLUICE
CRAWFORD								STOKERS					
PHILO								STOKERS					
TRENTON CHANNEL	27,067	25,140	0.83	10,470	210	16	VERTICAL FANTAIL	AIR COOLED SECTIONAL	MAIN CIRCULATION	1220	ELECTRO-STATIC PRECIPITATORS		
RICHMOND								STOKERS					
KEARNY								STOKERS					
AVON	30,600	30,600				16-8 ON EACH SIDE	VERTICAL FANTAIL		BOILER CIRC. SYSTEM	792		AIR OPERATED ASH GATES	SLUICEWAY
SOMERSET								FUEL OIL					
NARRAGANSETT	18,755 17,084	13,000 (NEW)	0.70 NEW 0.35 OLD	23,500	200	ORIG. BOILERS NOW HAVE CLOUCH BURNERS NEW 8	V. FANTAIL	WATER COOLED REFRACT. ON NEW BOILERS	NEW BOILERS BOTTOM & FRAM W. SLT. CIRC.	980	2-CINDERVANE 2-WELDED SCROLL SURF	HYD. ASH GATES WATER CIRCULAT.	TRUCKS
EDGAR								STOKERS					
LONG BEACH							FUEL	OIL AND GAS					
SEAL BEACH								OIL					
SUSQUEHANNA	14,770	11,000	0.75	12,300	225	6	VERTICAL FANTAIL	AIR COOLED HOLLOW WALLS	BOILER CIRC.	450	TO SLUICE	AIR OPERATED ASH GATES	SLUICE
CAHOKIA	18,010	11440 12,400	0.64	10,580 11,440	185 200	10	VERTICAL	ORIG. AIR COOLED SECTIONAL SEVERAL CHANGED TO FIN-TUBE & WATER SCREENED REFRACTRY.	BOILER CIRC.		CINDERVANE FANS		SLUICE
RIVERSIDE								STOKERS					
WAUKEGAN								STOKERS					
VALMONT	10,730	10,288 GROSS 8160 ABOVE SEP.	0.76	15,470	200	8	VERTICAL FANTAIL	AIR COOLED HOLLOW	BOILER CIRCULATION	302	HOPPER & SLUICE	HYD. OPERATED ASH GATES	SLUICE
HALES BAR								STOKERS					
BIG SIOUX	11,124	7810	0.76	20,700- 9800-AVE.	360 170	7	VERTICAL FAN TAIL	AIR COOLED SECTIONAL	BOILER CIRCULATION			ASH GATES	SLUICE
NEOSHO								STOKERS					
DRESSER								STOKERS					
EDGEWATER								STOKERS					
BARBADOES								STOKERS					
PINE GROVE								STOKERS					
IRON MT.	13,610	10,000	0.73			6 SSCR. FDRS FOR SAWDUST	V. FANTAIL	AIR COOLED	MAIN BOILER CIRCULATION		SEPARATORS AT CHIMNEY	2 BOILERS ASH 2 BOILERS STOKERS	GATES ERS AT BOTTOM
FORDSON	26,470	4-22,500 4-10,000 13,200			800 250 TO 300	24 12-ROUND NOZZLE 6-GAS	V. FAN TAIL BURNERS	FIN TUBE WATER COOLED SEP. CIRC. SYS. FROM BOILER	SEP. CIRC. SYS. FROM MAIN ST. HEADER	750-ARCH 710-FUR	NACE BOTTOM	REFRACTORY LINED	SCREW CONVEYORS
BROTHERHOOD OF L.E. BLDG.								STOKERS					
BETTENDORF								WASTE HEAT					
BAYONNE								STOKERS					

feeders from one motor and at Cahokia by driving ten feeders from one motor. At Narragansett one boiler is equipped with feeders of a recently developed type which meter the coal.

In the plants noted the standard 6-t. and 15-t. roller impact pulverizing mills have been installed in many cases. The screen type mill, however, has also been used, as in the installation at Columbia. At the Susquehanna station two roller impact, two screen type and one ball mill are used. Power consumption for these mills ranges from 12 kw-hr. per ton to 21 kw-hr. per ton, although this is for the mill system only. At Trenton Channel the average cost of pulverizing is 25.35 cents per ton, this cost including power, steam for drying, operation and maintenance.

As pointed out above, the figures for cubic feet of furnace volume for square feet of boiler heating surface vary between 0.35 and 1.0 with most of them about 0.7. Heating surfaces, as well as furnace volumes vary between extremely wide limits. The largest furnace tabulated is that at Avon which has 30,600 cu. ft. for a boiler with 30,600 sq. ft. of heating surface. At the Fordson plant each boiler has a heating surface of 26,470 sq. ft. The four newest boilers, recently rebuilt, have furnace volumes of 22,500 cu. ft., while the original four had furnace volumes of 16,000 and 13,200 cu. ft. The four latest furnaces are so designed that the boilers can be operated continuously at a rating of about 500 or 600 per cent, whereas with the old furnaces 200 or 300 per cent was about the maximum rating. This increase, of course, is due, primarily, to improvement in furnace design and to the fin-tube water-cooled walls.

Rates of Combustion

Rates of combustion will vary, of course, with varying conditions but Trenton Channel, Susquehanna, Cahokia and Big Sioux have rates of between 10,000 and 12,000 B.t.u. per cubic foot at boiler ratings of approximately 200 per cent. The figure for Narragansett is interesting as it shows a heat liberation of 23,500 B.t.u. at 200 per cent of rating. These figures, of course, are the averages and not the maximum figures. At Big Sioux, for example, the average heat liberation is 9800 B.t.u. per cubic foot at 170 per cent of boiler rating, whereas the maximum heat liberation is 20,700 B.t.u. at 360 per cent of boiler rating. As further progress is made in the development of water-cooled furnaces and in producing turbulent action of the coal and air jets in the furnace it may be expected that rates of heat liberation in excess of these will be attained.

In general, most of the boilers commented on here are set with the standard type of pulverized coal furnace in which vertical fan tail burners are set in an arch at the top of the furnace. At Columbia, nine vertical burners are used, with six horizontal burners low down on the side of the furnace. This arrangement was designed to produce turbulent action of the flame and, according to the latest reports from Columbia, has been successful in doing this. At Columbia, in addition to the furnaces and boilers commented on above a cylindrical furnace is also being tried out. This furnace has a diameter of 18 ft. and a height of 28 ft., with contents of 7110 cu. ft., with 15,100-sq. ft. boiler. This gives 0.47 cu. ft. of furnace volume per square foot of boiler heating surface. The burners in the cylindrical furnace are set to produce flame tangent to an imaginary circle inside the furnace and further interesting data on the combustion results obtained with this arrangement may be expected in the near future.

At Narragansett plant the original boilers are now equipped with turbulent burners while the new boilers have eight vertical fan tail burners each. At the Fordson plant vertical fan tail burners are used for the pulverized coal on the large furnaces, while on the four smaller furnaces round nozzle special burners are employed. Two burners are installed on each boiler to handle the blast furnace gas.

In many of the larger central stations air cooled sectional furnace side walls are used. The arrangement at Columbia has already been shown in some de-

AIR SUPPLY FOR PULVERIZED COAL FURNACES

PLANT	PRIMARY AIR				SECONDARY AIR			AIR PREHEATERS		ECONOMIZERS INSTALLED
	IN. OF H 20 STATIC PRESSURE	WHERE INTRODUCED	% OF TOTAL	CAPACITY OF FAN	IN. H 20 PRESSURE	WHERE INTRODUCED	% OF TOTAL	TYPE	CAPACITY	
COLUMBIA	5	AT FEEDERS	35		0	HOLLOW WALLS	65	TUBULAR	9868 SQ.FT.	YES
CRAWFORD						STOKERS				
PHILO						STOKERS				
TRENTON CHANNEL		AT FEEDERS			7.15	HOLLOW WALL DAMPERS		NONE INSTALLED		YES
RICHMOND						STOKERS				
KEARNY						STOKERS				
AVON	20	AT FEEDERS		2 FANS 11,000 C.F.M. EACH		HOLLOW WALL DAMPERS		NONE INSTALLED		YES
SOMERSET						FUEL OIL				
NARRAGANSETT		AT FEEDER				THROUGH WALLS		2 REGENERATIVE 1 TUBE TYPE 1 PLATE TYPE	40,000 SQ.FT. 15,000 " " 14,000 " "	NO
EDGAR						STOKERS				
LONG BEACH						OIL AND GAS				
SEAL BEACH						OIL AND GAS				
SUSQUEHANNA	15	AT FEEDERS	35			HOLLOW WALL DAMPERS	65	NONE INSTALLED		YES
CAHOKIA	15	AT FEEDERS	15	20,000 C.F.M.		HOLLOW WALLS	85	PLATE	ON 2 BOILERS 11,700 SQ.FT. EACH	NO
RIVERSIDE						STOKERS				
VALMONT	15	AT FEEDER		6400 C.F.M.		HOLLOW WALLS		NONE INSTALLED		YES
HALES BAR						STOKERS				
BIG SIOUX						WALL DAMPERS		TO BE INSTALLED		YES
NEOSHO						STOKERS				
DRESSER						STOKERS				
EDGEWATER						STOKERS				
BARBADOES						STOKERS				
PINE GROVE						STOKERS				
IRON MT.		AT FEEDER				HOLLOW WALL DAMPERS		NONE INSTALLED		NO
FORDSON	22	AT FEEDERS 200 DEG.	10		2.7	WALL DAMPERS 460-490 DEG.	90	PLATE	37,440	NO
WAUKEGAN						STOKERS				
BROTHERHOOD OF L.E. BLDG.						STOKERS				
BETTENDORF						WASTE HEAT				
BAYONNE						STOKERS				

FUEL OIL AND GAS BURNING, WASTE HEAT

PLANT	BOILER H.SURF EACH	FURNACE VOLUME	CU.FT. FURN. VOL. PER SQ.FT. H.S.	FUEL	BURNERS TYPE	BURNERS NO/BL.	AIR SUPPLY	FURNACE WALLS	AIR PREHEATER TYPE-SURF	ECONOMIZER SURFACE
SOMERSET	14,920	DESIGNED EQUIPMENT 19,100	FOR ULT. P.C. 1.28	FUEL OIL 18,375 B.T.U.	900 LB. AN HR. MECH. ATOMIZ'G	12	INTRODUCED AT BRIDGE WALL & IN SIDE WALL	AIR COOLED REFRACTORY	TUBULAR 10,712	9288
LONG BEACH	1-15,000 4-14,916	6,000	0.4	FUEL OIL 18,616 B.T.U. NAT. GAS 1,191 PER CU.FT.	COMBINED OIL AND GAS	15	THROUGH WALLS	8 WITH AIR COOLED WALLS + BOTTOM - 7 WITH WATER COOLED REFRACT. SIDE & FRONT & AIR COOLED FRONT	NOT INSTALLED	11,095 + 11,448
SEAL BEACH	24,450	10,375	0.425	FUEL OIL	COMB. OIL & GAS MECHANICAL ATOMIZING		FROM PREHEATR THROUGH BOTTOM TO BURNER	REFRACTORY	TUBULAR 23,025	NONE
BETTENDORF	3,005			WASTE HEAT	AUXILIARY FOR EMERGENCY			REFRACTORY	NONE	NONE

tail. This arrangement included an air-cooled ash hopper without a water screen. Primary air for the burners is brought through the hollow ash pit wall. Air-cooled walls are used in Trenton Channel and it is interesting to note that Avon, one of the largest recent central stations, is equipped with them. At Narragansett, water-cooled refractory walls are used on the new boilers. The water tubes on these walls are connected into the boiler circulating system. Susquehanna, Valmont and Big Sioux also use the air-cooled sectional wall design and the original installation at Cahokia was entirely of this type. Recently, however, several furnaces at Cahokia have been changed to include fin-tube water walls and water-screened refractories.

At the Fordson plant the four large furnaces are almost entirely water-cooled by fin-tubes, the side walls having a heating surface of 1800 sq. ft. The interesting feature in this furnace is that the side walls and the water screen at the bottom of the furnace are connected into a circulating system entirely separate from that of the boiler. This circulating system has its own super-heater and generates steam at boiler pressure and temperature, discharging it directly into the main steam header. Another interesting point is the water-cooled arch in these boilers in the Fordson plant. The water tubes of this arch have a heating surface of 750 sq. ft. per boiler and are connected with the main circulating system of the boiler. With this exception the general practice to prevent the ash from slagging in pulverized coal furnaces is to use a water screen at the bottom of the furnace through which the ash drops to an ash hopper below. As is shown, these water screens are usually connected directly with the main circulating system of the boiler.

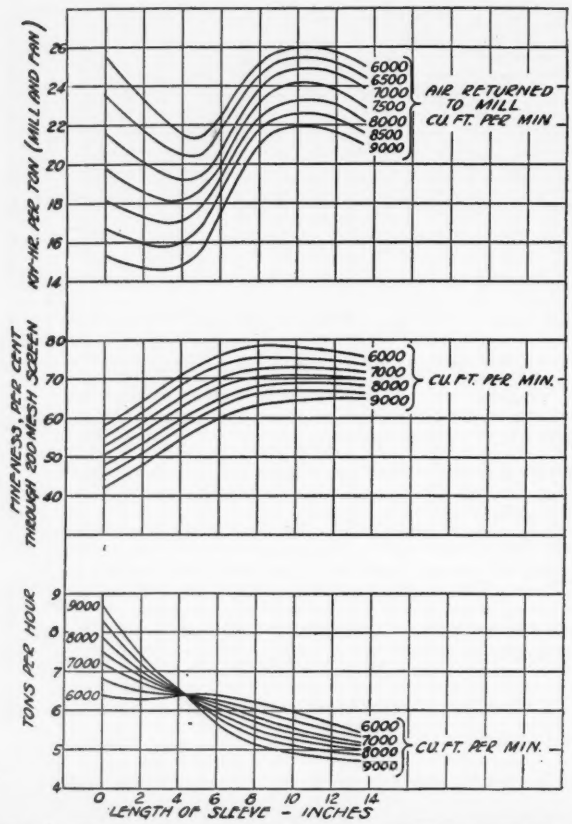


FIG. 3. EFFECT OF SLEEVE LENGTH ON PERFORMANCE OF A ROLLER MILL

Removal of Ash from Flue Gas and Ash Hoppers

Removal of ash from the flue gas receives attention in most of the stations under discussion. At Trenton Channel electrostatic precipitators are installed and recently, by making some changes in the arrangement of the electrodes, some very good results have been obtained. At Narragansett, two cindervane fans are used and two wetted scroll surfaces. Cahokia also uses cindervane fans. At Valmont, ash from the last pass and the breeching is sluiced down to the main ash sluice at

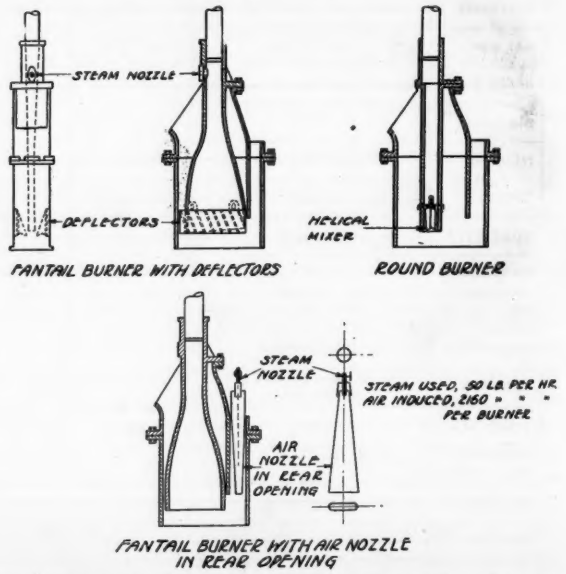


FIG. 4. TYPES OF BURNERS TESTED AT TRENTON CHANNEL

the bottom of the furnace. The design of the chimneys at Iron Mountain originally included separators at the bottom of each chimney.

Ash gates operated by air or water pressure are often used and, of the ten pulverized coal plants under discussion, seven employ a sluice-way for conveying this ash out of the plant. At Narragansett the hydraulic ash gates are provided with a water curtain through which the ash drops into trucks and is transported out of the plant. At the Fordson plant screw conveyors are installed directly in the bottom of the ash hoppers to remove the ash.

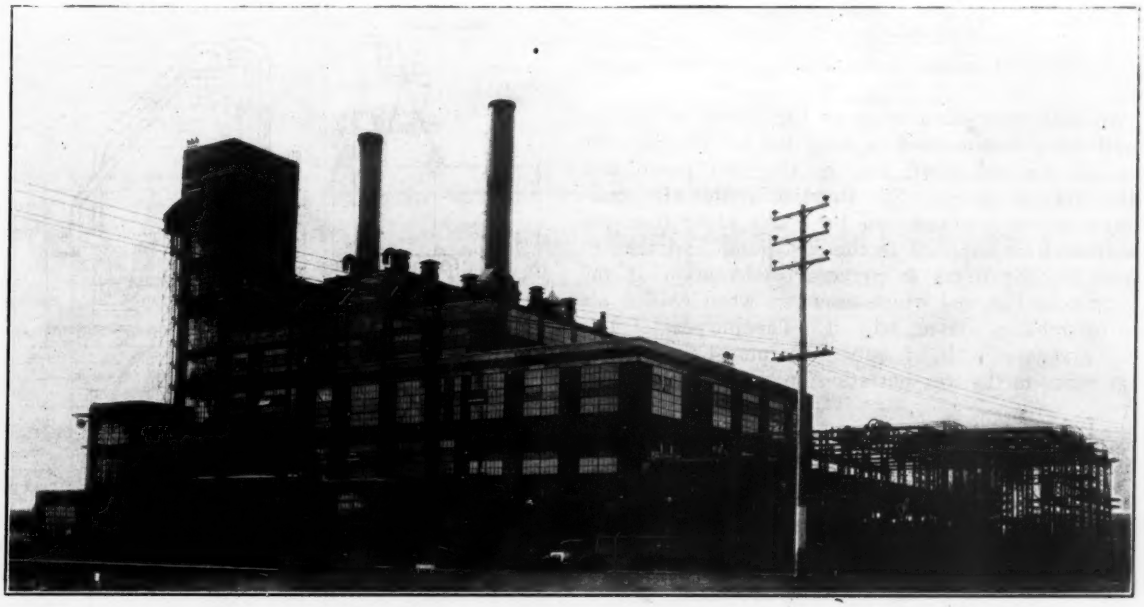
Concerning the supply of primary air for combustion in pulverized coal furnaces, this is generally introduced in the feeders. In most cases, as at Avon, Susquehanna, Cahokia, Valmont and Fordson, this air will be at a static pressure of between 15 and 20 in. of water. The secondary air, under a much lower pressure, is usually introduced through the hollow wall dampers. There is, of course, considerable variation in the percentages of primary and secondary air introduced at the respective points. Columbia and Susquehanna introduce about 35 per cent of the total air needed for combustion as primary air, while at Cahokia only 15 per cent of the air is primary air and at Fordson only 10 per cent.

Of the plants noted here, four are now equipped either entirely or partially with air preheaters and it is expected that they will be installed also at the Big Sioux plant. These heaters are of various types, Columbia uses tubular type heaters of 9888 sq. ft. of heating surface each; Fordson plant uses plate type preheaters, each with a heating surface of 37,440 sq. ft. Columbia also uses economizers. At Narragansett plant two regenerative rotary type heaters are installed, together with one tube type and one of the plate type.

At the present time the general opinion seems to be that, when turbines are to be bled for feed water heating, the air preheater takes the place of the economizers in the heat balance scheme since the temperature range through which the economizer would work would be much smaller. The argument has also been advanced that the air preheater in such a case adds the heat at the top of the temperature range, thus making the whole heat cycle more efficient. The fact remains, however, that at Columbia, Philo, and Twin Branch, to name only three important plants, steam is bled from several stages of the turbines for feed water heating and both air preheaters and economizers are installed.

Operating Difficulties Encountered

As noted above, some stations have had trouble with bridging of coal in bunkers and other parts of the coal preparation equipment. Frequently a simple change in the slope of the walls of the coal bunkers will prevent bridging but, at one station where this condition was found, these changes were not sufficient and agitators were installed just at the bottom of each pulverized coal bunker, the agitators being driven from the coal feeders. Several stations, such as Trenton Channel and Big Sioux, have made some experiments with the use of materials other than steel for the blades of mill exhausters and fans, owing to the trouble experienced from rapid wear of fan plates. Rubber, brass, micarta and various other materials have been used but in general it has been found that the steel fan plates are most economical.



THE BIG SIOUX STATION AT SIOUX CITY, IOWA

More attention than ever is being given to the question of cleanliness in pulverized coal plants, considering it both from the standpoint of safety to operators and equipment and also from the standpoint of waste of coal. At Trenton Channel, an ingenious arrangement of exhausters is installed on coal conveyors and the like, which picks up a great deal of material that would otherwise go to waste. At Big Sioux, Valmont and Narragansett, vacuum cleaning systems have been installed throughout the plant.

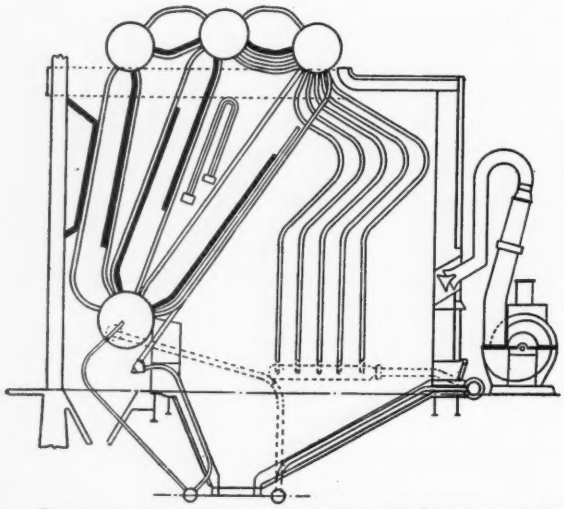


FIG. 5. UNIT PULVERIZER INSTALLATION AT BRUNOT ISLAND

Another interesting item at Big Sioux is the air conditioning system used to treat the air supplied for aerating the pulverized coal in the coal pump and transportation system. The function of this air conditioning system is to condense the water vapor from the compressed air supplied to the coal pump and then to reheat the air so as to prevent condensation of the moisture in the coal which occurred when chilled air was brought in contact with it. The purpose of this whole arrangement is, of course, to minimize trouble due to moisture in the transportation lines and bunkers.

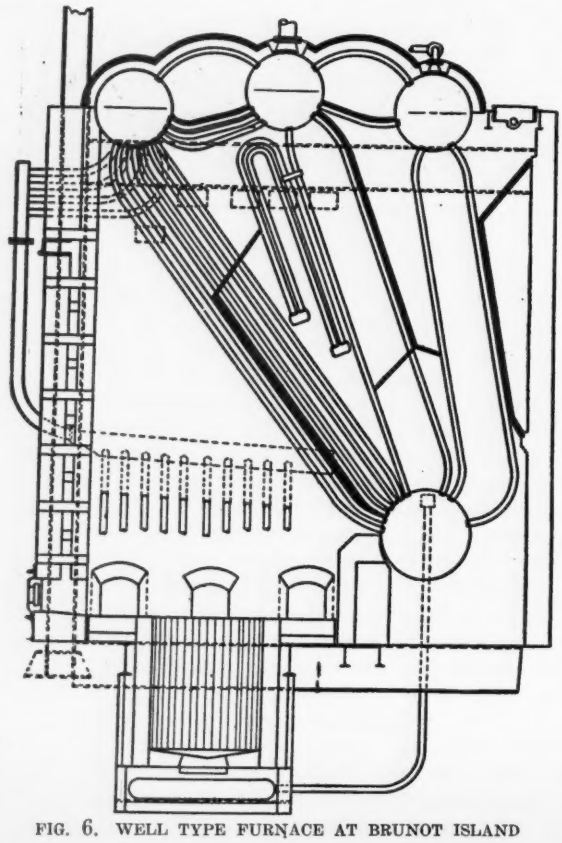


FIG. 6. WELL TYPE FURNACE AT BRUNOT ISLAND

Tests of Various Pieces of Equipment

At Trenton Channel some interesting tests of various pieces of pulverized fuel equipment were made, as noted in the 1926 Prime Mover Committee report of the N. E. L. A. Experiments on grid steam dryers indicated that the performance of the dryer was affected by variations in the initial moisture of the coal, in the amount of air passed through the coal and in the character of the air flow as influenced by three methods of baffling. Other tests on the pulverizing mills were made with various adjustments of the sleeve at the top of the mill used for adjusting fineness of coal and the curves in Fig. 3 show this effect. Several fan tail burners were modified as shown in Fig. 4 and it was found that of these arrangements, the fan tail burner, with deflectors in the casing but without steam injection,

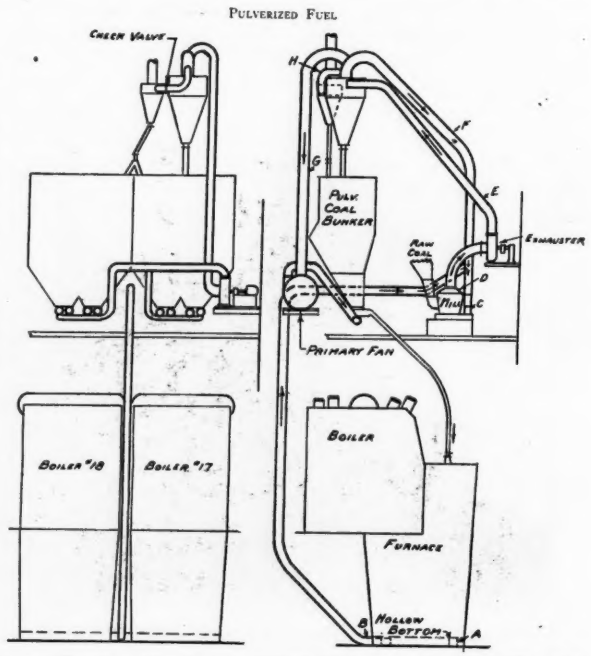


FIG. 7. ARRANGEMENT DEVELOPED AT ROCHESTER FOR SUPPLYING HEATED AIR TO MILL

seemed to offer the best solution of the problem of flame travel. At the Brunot Island station, not tabulated above, interesting experiments have been carried on with various types of furnaces and pulverizer arrangements as shown in Figs. 5 and 6. Figure 7 shows the arrangement for using preheated air in the pulverizing mill designed by the Rochester Gas and Electric Corporation. This arrangement has reduced the cleaning time for the mill to once a week, has eliminated the dripping of moisture from the bunker and the collection of moisture over the feeders and has greatly reduced feeding troubles.

The British Columbia Electric Railway Co., Vancouver, B. C., has plans for the construction of a new hydro-electric plant on the Bridge River, designed for an initial output of 50,000 hp., to be increased later. The output will be used largely by the Canadian Pacific Railroad Co. in connection with electrification of some of its lines in that section.

Stoker Improvements Meet High Ratings

Furnace Designs Limit Stoker Capacity; Water Walls, Radiant Superheaters and Preheated Air Are Reducing Furnace Sizes

IN ANALYZING the information secured from the various plants which are listed in the accompanying table, it is quite apparent that only two types of stokers are considered, these being underfeed and forced draft chain grate. Other types of stokers are of course considered for smaller boilers, such as those used in office buildings and industrial service, but where high rates of combustion are required the two types mentioned above are invariably chosen. In the plants where eastern bituminous coal is used we find in most cases that the underfeed stoker is installed. Where, however, anthracite or middle west bituminous coals which have a tendency to clinker are used, the forced draft chain grate has decided advantages.

Due to improvements in stokers and furnaces in which they are placed, somewhat higher rates of combustion are now obtainable than was the case a few years ago. With underfeed stokers for example, the rate of combustion varies from 45 to 60 lb. per square foot per hour for continuous operation, depending, of course, upon the character of the coal which is used. At times of peak load this rate may be increased to as high as 75 or 80 lb. for a period of two or three hours. Due to the characteristics of underfeed stokers they can handle rapidly fluctuating loads without difficulty, bringing a boiler from no load up to several hundred per cent of its rating in a very few minutes.

With forced draft chain grate the rate of combustion varies from 39 to 60 lb. per square foot of grate surface per hour with probably 45 lb. as the average throughout the country. With the highest rates of combustion the efficiency naturally falls off but a chain grate stoker can be operated at its highest rate of combustion continuously without necessitating a shut-down.

Stoker manufacturers state that their limiting factor is the failure of the refractory used in the furnace lining before the highest rate of combustion of which the stokers are capable is reached. It can readily be

STOKER PRACTICE

PLANT	HEATING SURF PER BOILER SQ.FT	COAL USED	TYPE OF STOKER	FURNACE DIMENSIONS HEIGHT	LENGTH	WIDTH	FURNACE VOL CU.FT.	GRATE AREA EFFECTIVE SQ. FT.	RATIO B.T.U. R.S. TO GRATE AREA	RATIO FURN. VOL. TO B.H.S.	STOKER DRIVE	METHOD OF AIR SUPPLY	TEMP OF AIR SUPPLY	ASH AND CLINKER REMOVAL	METHOD OF COOLING WALLS
COLUMBIA			P	U L	V	E	R I	Z	E	D		C O	A L		
CRAWFORD	SUPERHEATERS 6,000 W.S. 14,000 RENT	ILLINOIS	CHAIN GRATE	20'	17½', 18⅞'	24'	5910 6200	423 444	39.2 13.6	.355 1.03	MOTOR	FORCED & INDUCED	150° ABOVE ATMOSPH.	PIT, BUCKET AND CARS	NONE
PHILO	14,886	BITUMINOUS 10,800 B.T.U.	CHAIN GRATE	21'	22'	22'-4"	5430	356	39.6	386	MOTOR	FORCED & INDUCED	100° ABOVE ATMOS.	PIT, GRINDER AND SLUICE	NONE
TRENTON CHANNEL			P	U L	V	E	R I	Z	E	D		C O	A L		
RICHMOND	15,698	CLEARFIELD BITUMINOUS	UNDERFEED 15 RETORT	25'-6"	12'-8"	26'-½"	7800	362	42.7	.500	MOTOR	FORCED & INDUCED	NOTE 1	GRINDERS TO PIT	WATER COOLED
KEARNY	23,600	EAST. BITUM. 13,500 B.T.U.	UNDERFEED 15 & 16 RETORT	21'	16'-11"	28'-4"	8985 8472	480 460	49.25 51.3	.380 .357	MOTOR	FORCED & INDUCED	ATMOS.	GRINDERS	AIR COOLED CORBELING
AVON			P	U L	V	E	R I	Z	E	D		C O	A L		
SOMERSET			F	U E	L			O	I	L					
NARRAGANSETT			P	U L	V	E	R I	Z	E	D		C O	A L		
EDGAR	350 @ 19,743 1200 @ 15,732	NEW RIVER BITUMINOUS	UNDERFEED 16 15 RETORT	21'	.15'		9000 7750	423.5 429.7	46.7 36.7	.339 .493	MOTOR	FORCED & INDUCED	ATMOS.	GRINDERS, ASH CARS	VENTILATED WALLS
LONG BEACH			G	A S		A	N D		O	I L					
SEAL BEACH			F	U E	L			O	I L						
SUSQUEHANNA			P	U L	V	E	R I	Z	E	D		C O	A L		
CAHOKIA			P	U L	V	E	R I	Z	E	D		C O	A L		
RIVERSIDE	10,438	CENTRAL ILLINOIS	UNDERFEED 10 RETORT	16'	18'-2⅞"		5400	270	38.7	.518	HYDRA.	FORCED & INDUCED	250°	GRINDERS, PIT AND R.R. CARS	RADIANT SUPERH'T. AIR COOLED WALLS WATER BACK
WAUKEGAN	14,086	ILLINOIS	CHAIN GRATE 5 ZONE	16'-8" 20'-8"	18'-3"	21'	4300 5330	383	36 6	.307 380	MOTOR	FORCED & INDUCED	ATMOS.	ASH PIT TO R.R. CARS	NONE
VALMONT			P	U L	V	E	R I	Z	E	D		C O	A L		
HALES BAR	3-10750 2-16500	TENN. BITUM.	UNDERFEED 8 RETORT	13'-3"	20'		3-3405 1-5128 1-5525	3-223 2-357	483 463	.317 .311 .314 a	MOTOR	FORCED & INDUCED	190°	GRINDERS AND CONVEYORS	AIR COOLED CORBELING 2 REAR WALL WATER SCREENS 2 SIDE & R.W. WATER SCREENS
BIG SIOUX			P	U L	V	E	R I	Z	E	D		C O	A L		
NEOSHO	12,000	KANSAS	UNDERFEED	25'	14½	21'	6183 6358	272 305	44.2 39.4	516 530	MOTOR	FORCED	50° ABOVE ATMOS.	GRINDERS, ASH CARS	AIR COOLED TILE, CORBELING & WATER BACK
DRESSER	17,260	INDIANA	CHAIN GRATE	17'-3"	21'-4"	22'	4014	404	42.6	238	MOTOR	FORCED	ATMOS	TO BIN	NONE
EDGEWATER	14,643	E. OHIO BITUM. 13,800 B.T.U.	UNDERFEED 16 RETORT	21'	13½'		9015	383	383	605	MOTOR	FORCED	ATMOS	GRINDER TO PIT	NONE
BARBADOES	16,800	EAST. BITUM. 13,400 B.T.U.	UNDERFEED 12 RETORT	16'			4970	2875 PROJECT.	58 4	290	MOTOR	FORCED	ATMOS	DUMP PLATE	AIR COOLED
PINE GROVE	7,989	NO 3 BUCK ANTH. 11000 BTU	CHAIN GRATE	12'	18'-4"	10'-8⅝"	2246	1965	40.6	282	MOTOR	FORCED	ATMOS.	ASH PIT TO R.R CARS	
IRON MT.			P	U L	V	E	R I	Z	E	D		C O	A L		
RIVER ROUGE			P	U L	V	E	R I	Z	E	D		C O	A L		
BROTHERHOOD OF L.E. BLDG.	4,120	BITUM. SLACK	V TYPE				1037	80	51 5	251	ENG	NATURAL	ATMOS	STEAM JET	NONE
BETTENDORF			W	A S	T	E	H	E	A	T	&	O	'I L		
BAYONNE	10,200	ANTHRACITE NO. 3 BUCK.	CHAIN GRATE	13½'	18'	16'	2000	288	35.5	.196	ENG	FORCED	100°	ASH HOPPER TO CARS	NONE

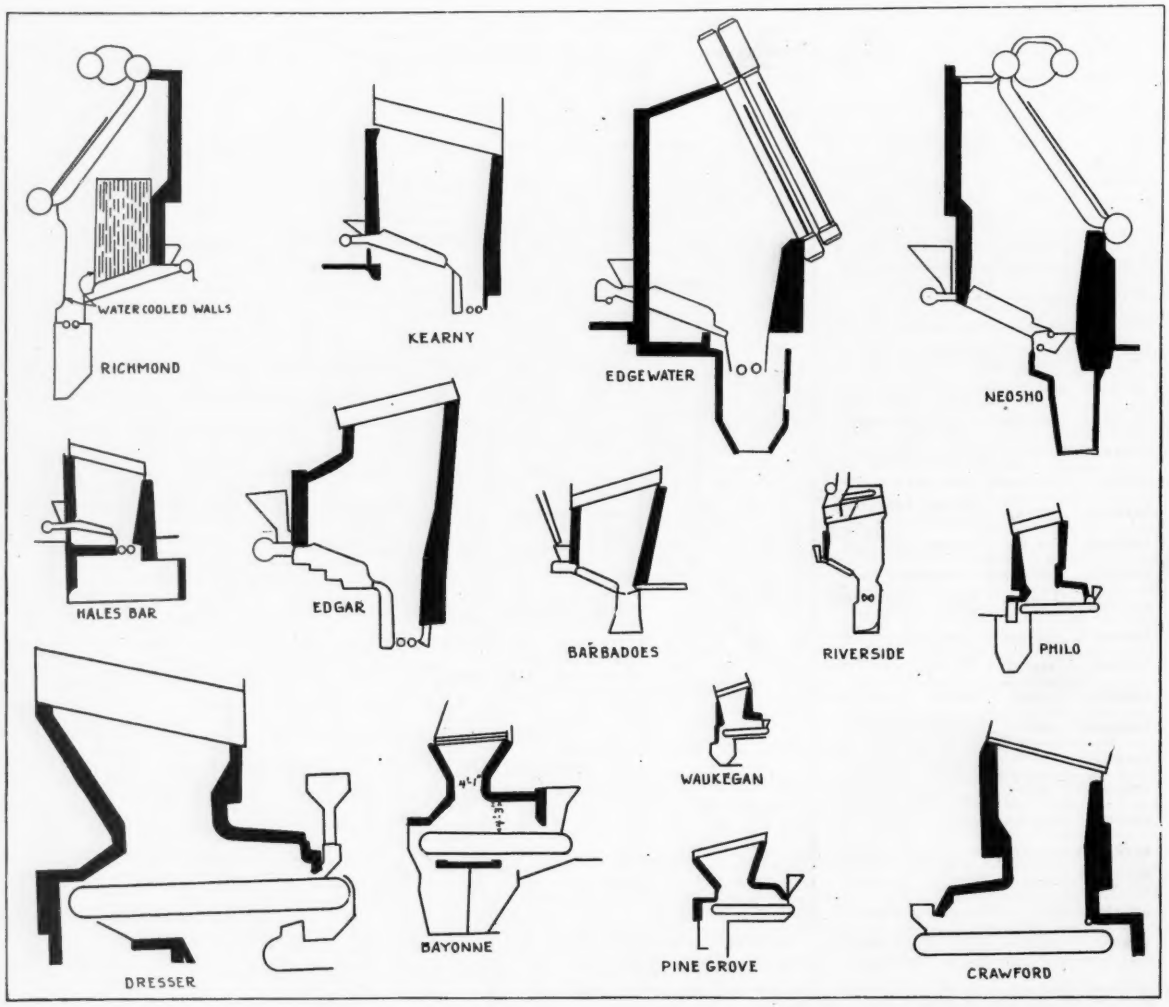
NOTE 1— AIR HEATERS OF 22,072 SQ.FT. INSTALLED

appreciated that with western lignite higher rates of combustion may be secured than with the bituminous coals of the east which have higher heat values. It can therefore generally be assumed that the lower the heat value of the coal, provided it has the same general characteristics as other coals with which it is compared, the higher the possible rate of combustion with a given furnace and stoker installation.

Air Supply and Preheating

In practically all cases, the entire amount of air required for combustion in underfeed stokers is supplied through the tuyeres along the side of the retort and through the perforated side plates along the sides of the furnace. This air is, of course, supplied under a pressure varying from 2 to 5 or 6 in. of water depending upon the load carried on the boiler.

While in most cases the air pressure at the various tuyeres is the same throughout the entire stoker, the Brooklyn Edison Co. reports to the N. E. L. A. that at its Hudson Avenue Station plans are made to admit air to ten separate parts of the stoker each individually controlled. A vertical partition is provided at the center of the stoker running parallel to the retort. This virtually divides the installation into two separate stokers as far as the air supply is concerned. The three dampers in the main wind box and the secondary wind box damper, which supply air to the lower overfeed tuyere section, are all intersected by the vertical front to back partition. Thus eight separate zones are provided below the tuyere section of the stoker. Air from the main ducts under separate damper control is also admitted to the agitator grates and front of the ash pit. An auxiliary air duct is provided for admitting air to the rear of the ash pit.



CROSS SECTIONS OF FURNACES SHOW SIMILARITY FOR STOKERS OF SAME TYPE

With forced draft chain grates from five to seven zones for the introduction of air are provided from front to rear, each zone is provided with a damper so that the proportionate amount of air can be definitely controlled by the operator. In addition to the air which enters the furnace through the grate it is customary at the present time to provide tuyeres for the introduction of air just under the front or at the rear of the ignition arch which break up the stratification of the combustible gases driving them against the incandescent fuel bed and causing a turbulence which is beneficial to com-

bustion. Where chain grate stokers are used for burning highly volatile coals such as those found in Iowa and Illinois, the provision of these mixing tuyeres is absolutely essential according to manufacturers of this type of stoker.

Within the last few years the use of preheated air has become quite generally recognized as a decided aid to combustion as it saves the necessity of heating the air from the temperature of the atmosphere up to that of the furnace. Experience has shown that an efficiency gain of 1 per cent can be secured by furnishing the stoker with air heated 30 to 40 deg. F. Both underfeed and chain grate stokers are now being designed for preheated air at temperatures as high as 400 deg. For this service, however, it is essential that the stoker be specially designed as the expansion due to such high temperatures is likely to give trouble unless provision is made in the design.

Furnace Size

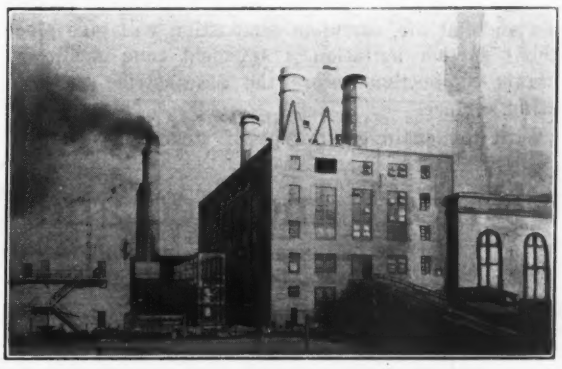
Fifteen or twenty years ago the prevailing volume of furnace was four or five times the area of the grate surface. Today, however, the volume has increased to 25 and even 30 times the active surface of the grate. The result is, of course, that higher rates of combustion and higher efficiencies are obtained than was previously possible.

Stoker manufacturers, however, are not so much interested in the volume of the furnace as they are in the height, that is, the distance from the active grate surface to the heating surface of the boiler. This dimension has gradually increased from 4 or 5 ft. of 20 yr. ago until we find in the plants listed in the table the height of furnace varies from 16 to 25 ft. This distance, it is considered, is essential to give time for thorough mixing of the gases and complete combustion before the gases reach the heating surfaces and are chilled below the ignition point.

For chain grate stokers, baffles are considered more important than volume and in many instances volume is sacrificed in order to provide baffling to reflect the heat and mix gases so as to secure proper ignition and gas mixture in the furnace proper.

Inspection of the accompanying table will show that the volumes vary widely. Considering for example, those plants where underfeed stokers are installed, that having the largest furnace per square foot of heating surface is the Edgewater plant with a figure of 0.605. Next to this is the Neosho plant with a figure of 0.530. The smallest furnace compared to the boiler is found at the Barbadoes Island plant with a figure of 0.290, and next to this is the Hales Bar plant with a figure of 0.311. These last two plants are supplied with bituminous coal, the volatile constituents of which are probably not as high as the middle western fuels. The average size of furnace for underfeed stokers has a value of 0.415 cu. ft. of furnace volume per sq. ft. of boiler surface.

Turning to the plants which are equipped with chain grate stokers, we find the highest and the lowest ratios in plants that cannot well be compared with the others. The highest ratio is found with the furnace that serves the reheat boiler at Crawford, the ratio being taken between the furnace volume and the water heating surface, whereas there is nearly twice as much reheat surface in the boiler as there is water surface. In the other extreme is the Bayonne plant with a ratio of 0.196. The special feature here is the fact that in this furnace anthracite buckwheat is burned whereas in the other plants bituminous coals are used. Taking out these two plants we find a more uniform ratio of furnace volume to heating surface than we have in the underfeed installations. The greatest volume is that employed at Philo with a ratio of 0.386 and the lowest is at Dresser with a ratio of 0.238. The average for all plants is close to 0.3 cu. ft. per sq. ft. of heating surface. It would appear, however, that furnace volumes have probably reached their maximum and within the next few years considerable reduction in volume will be noticed. This is due to the increasing use of water cooled side walls, bridge walls and radiant type superheaters, all of which have a tendency to reduce furnace temperatures which have been the limiting factors in combustion rate due to the destruction of furnace linings.



LONG BEACH STATION

Although we note in the column headed "Method of Cooling Walls" that many of the stoker fired plants are employing artificial methods such as water cooling, air cooled corbeling, ventilated walls, radiant type superheaters and water back, these methods are not universal but do show a trend in this direction which is being more fully carried out in plants now being constructed and designed.

Ash and Clinker Disposal

One of the principal problems which has been encountered particularly with underfeed stokers is the removal of the ash and clinker from the furnace. This difficulty has within recent years been quite definitely solved by the use of clinker grinders which operate continuously at a speed suited to the rate of combustion on the stoker, so that the clinker hopper is never empty, but the unburned fuel is given sufficient time to complete its combustion before it is discharged into the ash pit. It has been found in some plants that best service with single roll clinker grinders is secured when the roll turns against the bridge wall, thus preventing the entrance of air between the bridge wall and the fuel bed. Where double roll clinker grinders are used, however, the rolls turn away from each other and in this way keep a permanent seal against air entering the furnace.

With chain grate stokers the removal of ash and clinker is merely a matter of allowing the refuse to fall off at the end of the stoker into the ash pit from

which it may be removed by a clinker grinder thus preventing entrance of air around the back of the stoker or a seal may be formed across the end of the stoker by means of a water back set sufficiently close to the end of the stoker to form a seal through which air passes with difficulty.

Combustion Arches

Just what present practice is in regard to combustion arches in the furnace can best be shown by means of the cross section illustrations of the furnaces in the plants tabulated. There are, however, a few principles which govern the location of arches which it would be well to consider here. So far as the underfeed stoker is concerned there is little or no use for arches of any description. The unburned fuel coming up from beneath the fuel bed virtually passes through a retort in which its volatile constituents are driven off passing up through the incandescent bed of burning fixed carbon and ascending from the fuel bed a mixture of volatile gases and hot air, complete combustion will take place without further agitation if sufficient time is allowed for this combustion before the gases strike the cold heating surface.

With the chain grate type of stoker, however, an entirely different process of combustion takes place and arches are essential to complete combustion. As the green fuel enters the front of the furnace it must first be coked, then ignited and finally the fixed carbon burned before the rear of the stoker is reached. To accomplish this the usual method is to provide an ignition arch which will reflect the heat from the incandescent fuel bed near the center of the grate surface down upon the green fuel just inside the gate. This heat quickly drives off the hydro-carbon gases which, when properly mixed with the burning gases ascending from the center of the fuel bed, burn rapidly in the combustion space. Whereas in former practice it was customary to construct the ignition arch parallel with the grate there is a tendency at the present time to modify this construction somewhat by placing the arch at an angle as great as 45 deg. from the grate surface in some cases. In some plants a rear or bridge wall arch is constructed to reflect the heat from the hottest part of the fuel bed to the front of the grate. This arch at the same time has a tendency to mix the thin gases from the end of the grate with the richer gases at the center of the furnace. With properly designed arches fuels of practically every description can be burned without difficulty on chain grate stokers.

Forced, Induced and Natural Draft Practice

Developments in Draft Equipment Have Been in the Direction of More Effective Application Rather Than Improvement in Design of Equipment

STEAM BOILERS and furnaces have grown to such large proportions during the last few years and are required to operate at such high ratings that the use of either forced or induced draft or both has become an absolute necessity in most power plants. In fact, there are few plants in which the draft fans can be shut down for even a few minutes without seriously affecting operation. Studies of existing plants show that, on the average, forced draft fans can be interrupted for 1½ min. and induced draft fans one minute without causing trouble.

While no startlingly new developments in the design of draft equipment have been made recently, there has been considerable improvement in the existing types resulting not only in equipment having higher efficiency but also greater reliability. In view of the importance which the draft fans bear in relation to the entire plant operation, the factor of reliability is perhaps of even greater importance than efficiency. There has been a tendency on the part of manufacturers to build more rugged equipment; fans with heavier shafts and better bearings, more rugged motors and more reliable control equipment.

Motor-Driven Fans Are Becoming Popular

For driving purposes, motors are becoming more popular, as is indicated by the accompanying tabulation of draft data. Among the central stations listed, it will be seen that all of them use motors for driving both the forced and induced draft fans. In some cases, as for instance at Riverside and at Neosho, turbines are also installed, but motors are used for normal operation. In industrial plants, where forced draft is used, the tendency to use motors for driving the fans is not so pronounced and, while no definite conclusions can be drawn from the small number of plants on which data are available, because of the more prevalent use of steam-driven auxiliaries, the use of steam-driven forced draft apparatus is no doubt quite general.

Dual Motor Drive Has High Efficiency

In large plants, central stations and industrial power plants, there is a growing tendency towards the use of the dual motor arrangement. This permits the use of simple alternating current motors and gives the large range of speed and capacity demanded. With this arrangement two motors, a small one and a large one, are mounted on one fan shaft. The larger motor is energized only for the higher speeds and peak load conditions, while the smaller one operates at the normal load with resulting improvement in efficiency. Where the dual motor drive has not been adapted for this service, the brush-shifting type of alternating current motor has been installed in a number of plants and seems to be giving good satisfaction. This type of motor has excellent speed variation characteristics and is well adapted for remote control. Another type of motor for fan drive installed in some of the more recent plants is the two or three-speed induction motor, in which a limited number of definite speeds are obtained by changing the number of poles on the motor. This type of motor, which has long been in use on electrically-driven ships for driving propellers, has the advantage of being simple and reliable. They are easily controlled from remote points by pole-changing switches.

In line with the common tendency toward centralizing the control of all equipment in the boiler room at comparatively few points, the control of draft equip-

ment, regardless of its location, is from the operating floor in nearly all plants from which information was obtained.

The capacities of forced draft fans used, it will be noted, vary widely from 6400 cu. ft. per min. for a comparatively small plant to 225,000 cu. ft. per min. The latter figure is excessively large, however, and, as will be noted from the table, is not representative for even the larger plants. The average size in use is about 60,000 c.f.m. This figure, however, does not signify anything definite, since the size of the fans is dependent upon the sizes of the boilers and furnaces used. There is, however, a decided tendency towards the use of one forced draft fan per boiler, as is also the case with induced draft fans. This is the result, no doubt, of the practice to make each boiler with its associated auxiliary equipment a unit complete in itself.

It will be noted that there are a number of stations listed in the table as not having forced draft equipment. These plants are mostly pulverized coal installations where the fans cannot be classed strictly as forced draft fans. In most cases, however, where pulverized coal is used, the primary air fans, which force the fuel into the furnace, may be considered, to a certain extent, as acting as forced draft fans but, for the purpose of clearness in presenting the data, it was not thought advisable to include such fans in the table.

Practice in regard to the relative location of the forced and induced draft fans in the power plant is not indicated in the table, since this varies widely, depending upon the particular conditions existing at each plant. In plants not having air preheaters installed, in most cases, the forced draft fans are installed in the basement, so as to simplify the duct arrangement.

DATA ON DRAFT EQUIPMENT IN MODERN POWER PLANTS

PLANT	FORCED DRAFT							INDUCED DRAFT					NATURAL DRAFT		
	NO. OF FANS		FAN DATA			TYPE DRIVE	METHOD OF CONTROL	NO. OF FANS PER BOILER	FAN DATA		TYPE DRIVE	METHOD OF CONTROL	BOILERS PER STACK	TYPE STACK	HEIGHT OF STACK
	TOTAL	PER BOILER	CAP. C.F.M.	PRES.	SPEED				CAP. C.F.M.	SPEED					
COLUMBIA	8	1			600-750	DUAL MOTOR	R.F.B.P.	1		600-750	DUAL MOTOR	R.F.B.P.	4&8	S.B.L.	175
CRAWFORD	40	2	40,000			V.S. IND. MOT.	R.F.B.P.	1	115,000		VAR. S. IND. MOT.	R.F.B.P.	8	S. B. L.	150
PHILO	8	1	70,600	5"		DUAL MOTOR	R.F.B.P.	1	130,000		DUAL MOTOR	R.F.B.P.	4&8	S.	155
TRENTON CHANNEL			NO FORCED DRAFT					1	193,000	120-460	D.C. MOTOR		3	S. B. L. VENTURI	190
RICHMOND	12	1	60,000	9.8"	1165	V.S. IND. MOT.	R.F.B.P.	2	45,000	690	IND. MOTOR	R.F.B.P.	3	S.B.L.	81
KEARNY	12	1	134,000	7"		2-S. IND. MOT.	R.F.B.P.	1	225,000		2-S. IND. MOT.	R.F.B.P.	6	S.B.L.	258
AVON			NO FORCED DRAFT					1	195,000		B.S. MOT.		2	R.T.C.	175
SOMERSET	6	2	30,000	5"	1048 1760	B.S. MOT.	R.F.B.P.	1	110,000	252-814	B.S MOT	R.F.B.P.	5	CONCRETE	250
NARRAGANSET		1	50,000			V.S. A.C. MOT.		1	110,000	300-400	DUAL MOTOR			S	282
EDGAR		1	80,000	6"	1170	A.C. MOTOR		1	150,000	870	A.C. MOTOR		4	R.B.	128
LONG BEACH	15	1	60,000	2"	285-475	V.S. IND. MOT.		1	110,000	326-540	B.S. MOT		2	CONCRETE	126
SEAL BEACH		1				B.S MOT		1	100,000		B.S MOT.		6	CONCRETE	375
SUSQUEHANNA			NO FORCED DRAFT					1			3-S. IND. MOT	R. M. C	3	CONCRETE	200
CAHOKIA	8	½	20,000	15"		A.C. MOTOR	R.M.C.	1	I.D. FAN	USED ON 1 BOILER ONLY			4	R.T.C	325
RIVERSIDE	4	1	67,000	6"	VARIES	DUAL MOTOR ALSO TURBINE	R.F.B.P.	1	93,000	VARIES	DUAL MOTOR	R.F.B.P.	1	S.G.U.	30
WAUKEGAN	6	1	70,000	3.5"	VARIES	V.S. A.C. MOT.	R.F.B.P.	1	120,000	VARIES	V.S. A.C MOT.		3	S.B.L	150
VALMONT	4	1	6400	15"	1800	A.C MOTOR			NO INDUCED DRAFT USED				4	R.B.	331
HALES BAR	3 2		242,000 363,000	6.8		A.C MOTOR			281,600 422,400		V.S. MOTOR			CONCRETE	171
BIG SIOUX								1	110,000		DUAL MOTOR		2	S.G.L	69
NEOSHO	2		85,000	6½" 130"		MOT. TURBINE	R.F.B.P.		NO INDUCED DRAFT				3	CONCRETE	355
DRESSER	2		225,000	2-5"	305-514	A.C MOTOR			NO INDUCED DRAFT				2	S.B.L	275
EDGEWATER	3	1	85,000	6.5"		A.C MOTOR	R.M.C.		NO INDUCED DRAFT				3	R.B.	275
BARBADOES I.	3	1	65,000	7"	1280	IND. MOT	R.M.C.		NO INDUCED DRAFT				3	S.B.L.	300
PINE GROVE	6	1	37,500			C.S. A.C. MOT.								R.B.	350
IRON MT.			NO. FORCED DRAFT					1					2	R.B.	190
RIVER ROUGE		2	110,000	8.5"			M	2	215,000					S.B.L.	327
BROTHERHOOD OF L.E. BLDG.			NO. FORCED DRAFT						NO INDUCED DRAFT				4	S.	325
BETTENDORF								1	12,300		V.S. A.C MOT.				
BAYONNE	8	2				TURBINE	M		NO INDUCED DRAFT				4	R.B.	235

V.S. = VARIABLE SPEED. 2-S. = 2-SPEED. B.S. = BRUSH SHIFTING. C.S. = CONSTANT SPEED. R.M.C. = REMOTE CONTROLLED. R.F.B.P. = REMOTE CONTROLLED FROM BOILER PANEL. M. = MANUALLY. S.B.L. = STEEL, BRICK LINED. S. = STEEL. R.T.C. REINFORCED TILE, CONCRETE. S.G.U. = STEEL, GUYED, UNLINED. R.B. = RADIAL BRICK.

Where economizers or air preheaters are installed it is more usual to install the fans above the operating floor or even above the boilers, depending upon the flue arrangement and the physical dimensions of the boiler house.

A development with which most manufacturers of induced draft equipment are concerning themselves is that of providing means for the removal of dust and cinders. In some cases, the fans themselves are constructed with means for such cinder removal, while in others separate centrifugal dust collectors are installed, either ahead or after the induced draft fans. While there have been some applications of the latter arrangement, that is, placing the dust collector ahead of the fan, in most cases the former arrangement is preferred, since the dust collector is installed at the base of the stack; in fact, it then becomes an integral part of the stack itself.

Natural Draft

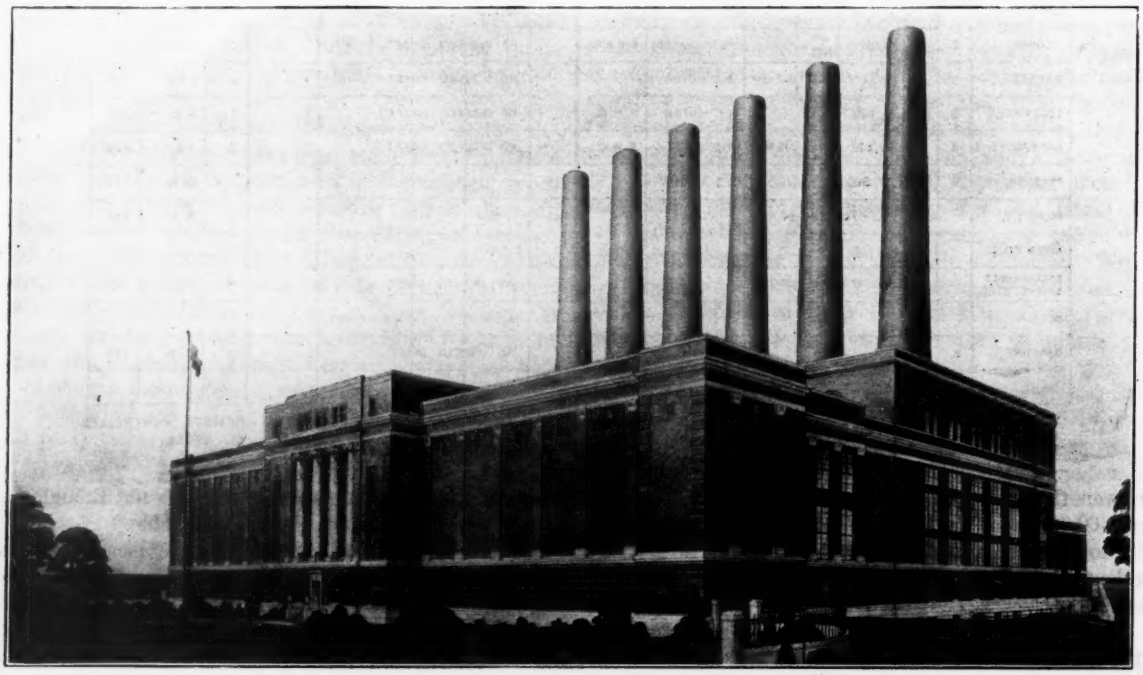
Natural draft, that is, the production of draft for combustion by means of a chimney is not relied upon to any considerable extent in central station power plants. Many industrial plants still depend upon the chimney for the draft but even in this class, particularly among the larger ones, where boilers and furnaces are required to operate at high ratings, forced and induced draft is being used to satisfy combustion air requirements. In such plants the chimney is provided merely to discharge the gases of combustion at a height sufficiently above the ground so that they will not cause annoyance to those living nearby.

Some of the modern central station plants have very short stacks in relation to the size of the plant, Crawford Ave. station in Chicago being a typical example. Both forced and induced draft are used at this station and, since there is no need for a tall chimney for the production of high natural draft, the chimneys have been made just high enough so as to discharge the gases above the roof. In another boiler house, that at Princeton University, the stack has been omitted entirely.

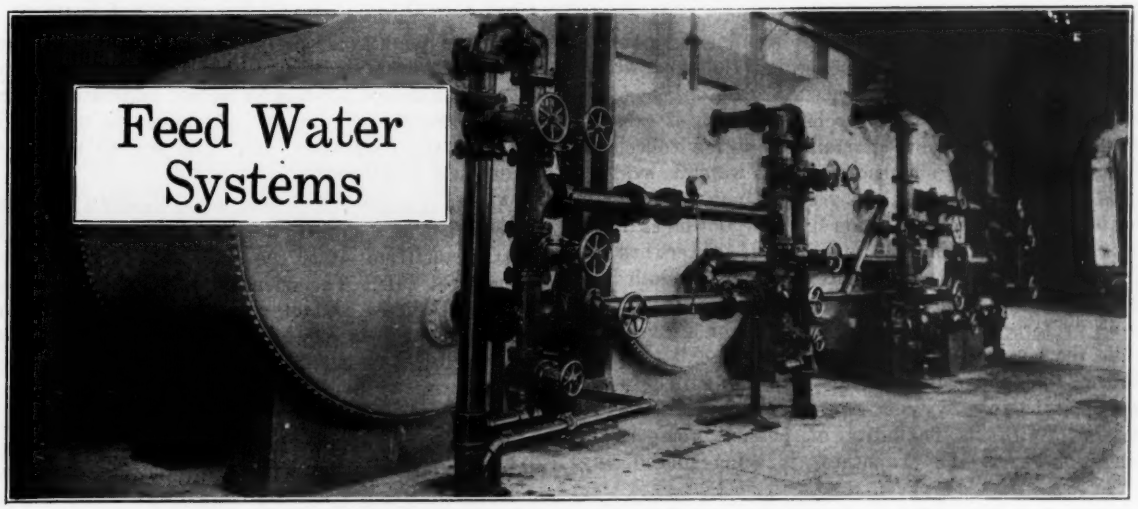
In many instances, however, the question of chimney height cannot be determined solely by the draft requirements or the engineering aspects of the case, for municipal ordinances are often the ruling factors. These ordinances, having been formulated in the early days before scientific combustion methods had been evolved and when smoking chimneys were more prevalent than they are now, usually specify that chimneys shall not be lower than a certain specified height above the ground. It is to meet the requirements of such ordinances that high chimneys are often provided today, where, if combustion and draft considerations were taken into account, no stack or at least only a very low one would be needed.

Chimney design for power plants varies considerably and, as may be noted from the tabulation, does not follow any definite order for a particular size or type of station. As a rule, stacks are of one of three kinds, steel, concrete or brick or tile. The problem of which kind of stack to provide is largely one of cost, architectural design and location. Where a stack is to be set on the building steel, the most usual practice is the provision of a steel stack. Where the stack is set on its own foundation, one of brick or concrete is more often provided.

The stack heights given in the table must not be taken too seriously, since it was not always possible to obtain accurate information as to what was meant by stack height, whether the height given was that above the operating floor, above the roof or above the ground.



AVON STATION OF THE CLEVELAND ELECTRIC ILLUMINATING CO.



Recent Developments in Feed-Water Treatment

PRACTICE IN CHEMICAL METHODS OF TREATMENT, EVAPORATION, DEAERATION, AND STAGE FEED WATER HEATING. BY E. H. TENNEY*

ALONG WITH THE recent evolution toward higher steam pressures and boiler ratings it has become necessary to perfect the methods of feed-water treatment in order to meet the more severe conditions of boiler and general plant operation. At the same time the advantages of bleeder heating have become more apparent and elaborate station heat balance systems have resulted. The two developments have been co-related to the extent that certain steps in feed water treating, such as distilling and deaerating water for boiler use, have been combined with steps of feed water heating, in evaporators, deaerators and other units. The developments of the past few years as well as the possible trend of future changes may be judged by the design in recent plants. Some of the outstanding advances can be summarized briefly as follows:

WATER SOFTENING

The necessity for feed-water treatment in order to prevent the formation of scale as well as foaming and priming, has, of course, been long appreciated. The more usual systems include:

(1) A raw water chemical treatment, such as lime and soda ash, depending upon the nature of the water supply.
(2) Zeolite systems.
(3) Hot process continuous softeners, and
(4) Boiler compounds.

The purpose of all such systems is to precipitate or break down the scale forming salts so that they may be drawn off through the boiler blow down. Systems and qualities of water, however, that proved satisfactory for former low steam pressures and boiler ratings when adapted to the higher pressure practice have not functioned properly. At 350 lb. to the square inch, waters which formerly were considered as excellent, may permit the formation of thin scale, which at high ratings cause burnt tubes and blowouts. In some high pressure plants, where a greater part of the make-up water is distilled from evaporators and soda ash has been used as a treatment for condenser leakage, scale has been encountered. This condition has been studied in the investigation of Dr. R. E. Hall of the Bureau of Mines on the mechanism of scale formation. The results of this investigation, initiated in 1922 and still continuing, have constituted a very valuable contribution to the practice of boiler water conditioning. An important result has been to substitute (or at least to supplement) the use of sodium phosphate for sodium carbonate (soda ash) in some high pressure plants. This is based on the fact that the rate of decomposition of sodium carbonate is increased at high pressures and is very marked at pressures over 350 lb. It is consequently impossible to maintain the carbonate concentration in proper relation to the sulphate concentration, with the result that a sulphate salt may precipitate to scale. The question of the proposed sulphate-carbonate ratio is coming in for much consideration at the present time.

The subject of caustic embrittlement has also caused considerable discussion and some controversy during the past few years. Although some phases of the embrittlement of metal are still unsettled, sufficient information has been obtained to indicate that the action may be prevented by the proper treatment of feed water. Where embrittlement is indicated it is now the practice in high pressure plants to maintain a sulphate—causticity ratio of three; this has been accomplished by the use of dilute sulphuric acid with success. These developments have naturally been reflected in the water treatment systems and equipment of the latest plants.

The necessity for a very high grade of boiler feed water has led to the adoption of distilled make-up plants, or evaporators, in a great many of the larger central stations. The evaporator may be used alone or, as is more usual, it may be used in conjunction with feed water treatment, chemical or otherwise. As an evaporator is in effect a small boiler it is subject to

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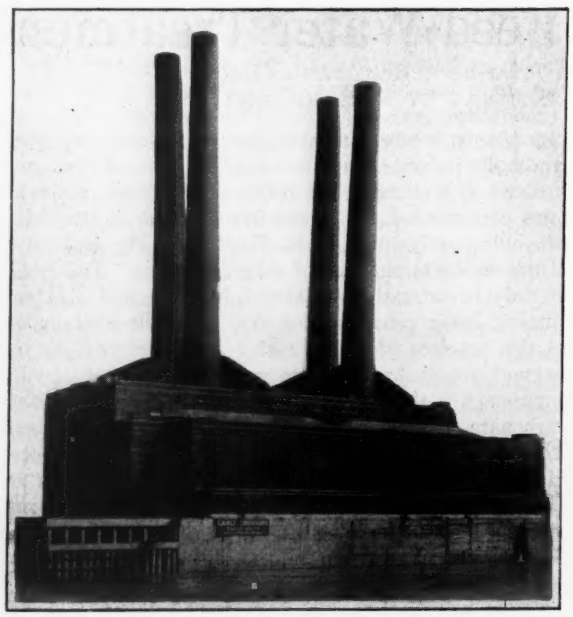
the same water troubles as a boiler, namely, scale, foaming, and priming, and the present trend is to give the evaporator water conditions somewhat the same attention as is given to boiler water. As scale on the evaporating tubes is most likely to be the cause of greatest difficulty, the importance of maintaining low concentrations and supplying an unscaling feed water is evident. As all the solid matter that is removed must pass out in the blow down, the regulation of blow downs is being given much attention and one manufacturer has developed a system for continuous blow down. Both high and low pressure units have been developed, the former being preferred for its higher capacity for a given size, while the low pressure unit with a lower exit temperature of the condensing medium is better suited to certain heat balance systems especially those with economizers. With its flexibility of possible temperature range, however, the evaporator is being placed any-



CAHOKIA STATION OF THE UNION ELECTRIC LIGHT AND POWER CO.

where from immediately after the condenser to after the third level heater, although the more customary position appears to be between the second and third levels. Steam for the evaporator may be from an auxiliary exhaust, high pressure steam (full boiler pressure is rarely used, however) or turbine bled steam. Due to the economy of bled steam there appears to be a growing tendency to use this source.

Deaerators

The importance of oxygen free feed water for the purpose of restricting boiler corrosion has long been realized but the advent of high pressures requiring steel economizer tubes, and high boiler ratings have stressed this importance. Consequently closed feed water systems and deaerators utilizing the boiling principle to remove entrained gases, have come into very wide use. The improvement in hot well design and the closing of the feed water system have aided materially in reducing the quantity of air in the feed water but deaerators have proven so efficient that further improvement in hot well design appears to be not imperative. Practically complete elimination of oxygen is usually obtained in the deaerators, and little serious mechanical trouble has developed.

As the deaerator is a feed water heater also, it may be regarded as a step in the heat balance system. Exhaust steam from either the main unit or auxiliaries is the general rule. The open types in which the steam comes into direct contact with the water are the most efficient heaters to the extent that the terminal temperature differenc is close to zero.

Stage Feed Water Heating

The heating of feed water in successive stages in closed heaters was developed with the advent of stage bleeding of steam from the main units. The economic advantage in saving the latent heat of the turbine exhaust steam, otherwise lost in the cooling water, is well known. At the present time all large turbines are equipped for two to four-stage bleeding and the newer plant heat balances usually include two or three-stage heating of the feed water when economizers are used and three or four-stage heating when without economizers. As the temperature of the bled steam depends to some extent on the condenser vacuum the various steps in feed water temperature vary with the season. This variation must be allowed for when exhaust steam from auxiliaries is used in a heater at an intermediate temperature level; to this extent the use of auxiliary exhaust steam is today somewhat at a disadvantage.

The heaters are of the closed type in the latest plant designs and have not required much development work. Earlier practice allowed for a 5 degree terminal temperature difference but actual results have been much lower, many reports of 2 deg. and less having been made. Jet condenser heaters have been coming into use to quite an extent. They operate on the principle of jet condensers in which the condensate is sprayed into a chamber coming in direct contact with the steam. Such heaters may also be used to advantage in removing entrained gases in the feed water.

Other sources of heat for feed water include generator air coolers, turbine oil coolers, and transformer oil coolers. It is now being generally recognized that the generator air cooler is a more efficient method for cooling the generator than for heating the condensate, and the present tendency appears to be toward the use of raw water for this purpose. As transformer oil coolers utilizing condensate frequently require great quantities of piping this method also is somewhat out of use in the latest designs.

Economizers

Flue gas economizers for heating the boiler feed continue to be used extensively. Two factors, however, have tended to reduce the use of economizers somewhat.

They are (1) the economy and effectiveness of stage feed water heating, and (2) the improvements made in the design of air preheaters utilizing flue gases. There have been no radical changes in economizer design during the past few years.

Feed Water Treatment in Power Plants

Higher Steam Pressures and Demand for Higher Ratings Have Made the Feed Water Treatment Problem of Vital Importance

EXPERIENCE has shown that with few exceptions most waters used for steam generating purposes in modern plants require treatment of some kind in order to maintain the operation of the boilers at the best point of efficiency and to preserve the materials of which they are made against deterioration. Pure water, assuming that it contains no oxygen or other dissolved gases, makes good boiler water; that is, it will have no detrimental effect upon the boiler material and when evaporated will leave no scale deposits. Pure water, however, is one of the rarest things in nature and most waters contain impurities in the form of dissolved solids or gases in varying degrees. Even rain waters, when they are caught in containers and are not permitted to come in contact with the earth, contain carbon dioxide and other gases taken up in their downward passage from the clouds.

When power plants were small and when boilers were not operated at from 150 to 500 per cent rating a moderate amount of scale-forming material in the boiler water did not matter greatly. The accumulation of scale was slow and the little that did accumulate was easily removed by periodic cleaning. With the high capacities and high ratings in use today, however, even a moderate amount of scale-forming impurities in the water will cause a rapid accumulation of scale, making it more and more desirable to install water treating equipment..

The degree to which feed water treating equipment is being used is reflected in the accompanying table where it will be noted that of all the central station plants on which information was available there are only two which have no feed water treating apparatus. One of these is the Valmont station in Colorado, which obtains its water from a nearby glacier. Glacier water, of course, is as nearly pure water as can be obtained in nature.

Systems of treatments used in these plants vary considerably according to the kind of raw water available, the type of plant, and, to a certain extent, upon the individual preference of the designer. The two principal forms of treatment available are either chemical treat-

FEED WATER HEATING AND TREATING

PLANT	METHOD OF PURIFICATION					FEED WATER HEATING											REMARKS
	RAW WATER	SYSTEM OF PURIFICATION	DEAERATOR	EVAPORATOR		SOURCE OF HEAT	TYPE HEATER	FINAL F.W. TEMP.	STAGE HEATING								
					TYPE				1ST. STAGE		2ND. STAGE		3RD. STAGE		4TH. STAGE		
									TEMP.	PRES.	TEMP.	PRES.	TEMP.	PRES.	TEMP.	PRES.	
COLUMBIA	RIVER	LIME-SODA – FERROUS SULPHATE	YES	NO		E. S.	O. & C	213°		2.9		9.7					ALSO AN OPEN HEATER USING HI ST. STEAM
CRAWFORD	H.S.F.-SED	Z.-ACID H. - D.-E	YES	YES	4-EF.	E. S. & AUX.	C		VARIES ON DIFFERENT UNITS								2 DEAERATORS INSTALLED ORIGINALLY BUT CLOSED SYSTEM NOW USED.
PHILO	RIVER WATER	L-S. D. E.	YES	YES	4-EF. FILM	E. S.	O. & C				VARIES						STAGE HEATERS, CLOSED. 1 OPEN HEATER.
TRENTON CHANNEL		EVAPORATORS	NO	YES	1-EF. SUB.	E. S	C. COND. TYPE		70 153	3.1	135 186	9.7	196 248	32			
RICHMOND	S.F. RIVER	EVAPORATORS -	YES	YES	2-EF.	E. S.	C. 4-PASS-HOR.	305°	161	5.6	247	28.3	303	78.2			
KEARNY	RIVER		YES	NO		E. S.	C. FL-H. COND.	325°	150	8	213	15	260	36	325	113	
AVON	LAKE ERIE	NOT TREATED - 15 DEAERATED	YES	NO		E. S. & A. E	O. & C.	200°	BLED AT 14TH STAGE ONLY - PRES. 6.05 LB.								WATER DEAERATED IN HEATER CONDENSER
SOMERSET	H.S.F.	EVAPORATOR - DEAERATOR	YES	YES	2-EF.	E. S. & A. E	C. 4-PASS, FL-H.		126	3	225	17	270	38			
NARRAGANSETT	S.F.	HOT LIME-SODA - D	YES	NO		E. S.	C.	325°	STEAM BLED FROM 8, 12, 14 & 17 STAGES								
EDGAR	RIVER	EVAPORATOR - DEAERATOR	YES	YES	3-EF.-HHL	E. S	C. 4-PASS, FL-H.			2.4		23.1		128.4			
LONG BEACH		EVAPORATOR - DEAERATOR	YES	YES	2-EF.-LHL	E. S.	C. 4-PASS, FL-H.	275-300°	142 163	3.6 8.8	176 204	14.7 13	307 337	70.8 123			
SEAL BEACH		EVAPORATORS			1-EF. SUB.	E. S.	C. FL-H.	368°	184* 152		153* 212		230* 278		295* 362		* THESE TEMPS. ONLY APPROXIMATE. THEY VARY WITH EVAPORATOR OPERATION.
SUSQUEHANNA	WELL WATER	ZEOLITE	YES	NO		E. S.	C.	320°*	137	3.32	196	12.9	212	38.5			* LEAVING ECONOMIZERS
CANOKIA	H.S.F. MUDDY	IRON SULPHATE - CALCIUM HYDRATE BARIUM HYDRATE	YES	YES	2-EF.	E. S. & H.T. E	C. FL-H.	260°	83		90		140		210		
RIVERSIDE	RIVER & WELL WATER	EVAPORATORS	NO*		1-EF. H.P.	E. S.	C	351°	102 141	2 5	141 205	10 15	205 298	ECON.	298 331	149	*DEAERATION IN CONDENSER
WAUKEGAN	LAKE - H	SAND FILTERS - ZEOLITE	NO	NO		E. S.	O & C.	220°	142 150	3.8 7.3	212 215	15 28.4					*OPEN HEATER USED FOR MAKEUP
VALMONT	GLACIER	NO TREATMENT	YES			E. S.	C. 2 & 4-PASS		132	9	169	19	234	66.5			
HALES BAR	RIVER	EVAPORATORS		YES	2-EF. L.P.	E. S.		210°		35		135					
BIG SIOUX			YES	YES	2-EF. H.P.	E. S.		230°	140	13	210	3.7					* DEAERATION IN CONDENSER
NEOSHO	RIVER WATER	FILTERS AND EVAPORATORS		YES	2-EF. H.P.	E. S.	C.										
DRESSER	RIVER WATER	SAND FILTERS - EVAPORATORS		YES	2-EF. H.H.L	E. S. & AUX. E	C.	240°	VARY WIDELY WITH LOAD								
EDGEWATER	LAKE WATER	INTERNAL TREATMENT	YES	NO		EXHAUST S.	O. DEAERATING	210°									
BARBADOES I.	RIVER WATER	SAND FILTERS AND EVAPORATORS		YES	2-EF.	E. S. & EVAP.	O. & C.			18.5 4.2		16.9					BLED AT ONE STAGE ONLY ON FIRST UNIT 2 STAGE BLEEDING ON 2ND UNIT
PINE GROVE	RIVER WATER	PRESSURE FILTER	YES	NO		HOUSE T. E.	O. DEAERATING										
IRON MT.		LIME SODA - HOT PROCESS - FILTER	NO	NO													
FORDSON	RIVER	SODA ASH	NO	YES	2-EF	SEE REMARKS	OPEN	205°									LIVE STEAM TO EVAP. AND AUX. EXHAUST
BROTHERHOOD OF L. E.	SLIGHTLY H.	NOT TREATED				EXHAUST S.	OPEN	212°									
BETTENDORF	RIVER	ZEOLITE					OPEN	160-180°									
BAYONNE	HARD	SULPHATE OF IRON - LIME - SODA				EXHAUST S.	OPEN	212°									BOILER PLANT ONLY

H.S.F. - SED. = HARD SCALE FORMING - SEDIMENT. S.F. = SCALE FORMING. H = HARD. Z = ZEOLITE N. = NEUTRALIZING. D. = DEAERATOR. E. = EVAPORATOR EF. = EFFECT. SUB. SUBMERGED
H.H.L. = HIGH HEAT LEVEL L.H.L. = LOW HEAT LEVEL HP. = HIGH PRESSURE. L.P. = LOW PRESSURE. E.S. = EXTRACTION STEAM. A.E. = AUX. EXHAUST H.T.E. = HOUSE TUR EXHAUST
O. = OPEN. C. = CLOSED. FL.-H. = FLOATING HEAD

ment or evaporation. Chemical treatment does not necessarily remove the harmful impurities from the water but either neutralizes them so that their effect is harmless or exchanges the harmful impurities for others that are not harmful. With evaporation, on the other hand, all the impurities, harmful and otherwise, are removed, and perfectly pure water delivered to the boiler.

During the past few years the use of the evaporator in power plants has become much more popular than it was at one time, a condition which has been brought about by the increasing need for pure boiler water. This tendency towards the use of evaporators is well shown in the tabulation, where of the 22 central stations on which data were available, 13 of them are provided with evaporators. It is, of course, not wise to draw any definite conclusions from such a comparatively small list

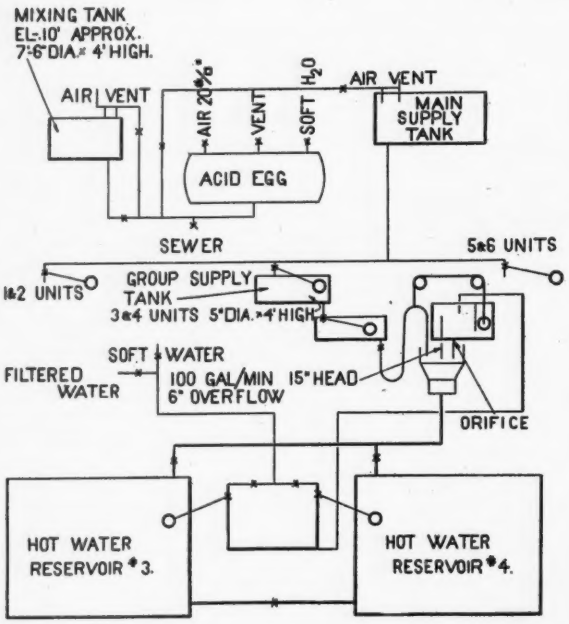


FIG. 1. PIPING DIAGRAM OF ACID TREATMENT PLANT USED BY COMMONWEALTH EDISON CO.

of plants but, since this list has in it some of the largest plants in the country, it is not entirely meaningless.

The use of absolutely pure water, as produced by the evaporator, has made apparent the need for apparatus to effect the removal of oxygen and dissolved gases, for it was found that even when evaporated water was used, there was trouble due to corrosion. This corrosion, it has been fairly well established, is due to the action of the dissolved oxygen in the feed water. The action of such dissolved oxygen on boiler metals is greatly accelerated at the high temperatures occurring in steam boilers.

It is for the removal of these dissolved gases that deaerators and deaerating heaters have come into extensive use. It will be noted that with only one or two exceptions, all of the stations listed use separate deaerators or deaerating heaters. This is the case, not only in stations using evaporators but also in those having other methods of treating their feed water.

The use of evaporators, together with deaerating apparatus of some kind, seems to be highly satisfactory from an operating standpoint and it has been demonstrated that boilers using evaporated and deaerated water can operate for as long as a year at a time without a trace of scale accumulating.

Development in equipment for the treating of feed water by chemical means has gone forward steadily during recent years and plants of all sizes are using such equipment. Both the zeolite process and the Lime and Soda process, it will be noted, are in extensive use.

Caustic Embrittlement and the Acid Treatment

The subject of caustic embrittlement in steam boilers has always been a point around which much discussion has taken place but in the light of recent research it is of particular interest at the present time. It is claimed that in certain processes of treating makeup feed water the content of bicarbonate of soda is increased. As a result of this under the present boiler practice of high pressure and temperature, the boiler waters reach a relatively high causticity, due to the conversion of the sodium carbonate (Na_2Co_3) to sodium hydrate (NaOH).

It is this condition of high causticity that is considered contributory to what is generally known as caustic embrittlement. The caustic soda attacks iron with the generation of nacent hydrogen which, having a natural affinity for metals, enters into the texture of the iron and modifies its physical properties with the resultant formation of cracks or brittleness. This theory has been advanced because cracks have been found in or near riveted seams of a small number of steam boilers fed with artesian well waters, high in sodium carbonate and low in sulphates, and also in some boilers fed with distilled water to which large amounts of soda ash have been added.

To counteract this action it has been proposed by those advancing the theory to maintain a ratio of sodium sulphate to sodium hydroxide in the boiler salines that is greater than one, in the hope that it may be beneficial to internally stressed material. There is disagreement on this point, however, and the manufacturers of water treating equipment, although they have developed and installed apparatus for maintaining the desired sodium sulphate, sodium hydroxide ratio, they do not necessarily subscribe to the theory.

Neutralizing System Used by Commonwealth Edison Co.

The Commonwealth Edison Co. has installed equipment of this kind in the Calumet station in Chicago, where the zeolite method of water treatment is employed. A system is used in which the zeolite treated makeup is treated with acid just before its injection into the station hot water reservoirs.

The station makeup is drawn from these reservoirs, the water of which is largely diluted with certain trap and heater drainages. This system was described in the 1925 report on feed water treatment issued by the N. E. L. A., the drawings of which are reproduced here. Figure 1 is a diagrammatic sketch of the system, while Fig. 2 shows more in detail the method of feeding acid to the zeolite treated water.

It has been found in using this equipment that, in order to obtain the desired sulphate—causticity ratio

in the boiler water—the acid treatment requires that the alkalinity of the zeolite treated makeup be reduced from 7 grains to 2.5 grains per gal. The variation in the alkalinity of the acid treated zeolite water is the guide for the quantity of acid to be fed into the system. The acid used with this system is commercial sulphuric acid of 1.84 specific gravity. It is claimed that this installation was made mainly with the idea of establishing conditions incident to acid treatment of feed water and the mere fact that caustic embrittlement has not occurred with its use is no proof that it would have occurred if it had not been used.

Naturally with a new apparatus of this kind certain operating difficulties are bound to occur and some of these troubles are described in a statement by the Commonwealth Edison Co. in the 1926 Feed Water Treatment report of the N. E. L. A. The handling of the dilute acid from acid egg to supply tanks was by means of lead lined piping. Experience has shown, however, that if the lead coating is not perfect, corrosion will take place, and it has been found necessary to replace some lines with lead piping in conduit. In the case of the smaller piping and fittings in connection with floats and acid feed control box, group supply tanks, and many chambers, it has been found that corrosion troubles were eliminated by the use of bard rubber.

Some difficulty was had with corrosion of the acid container, which was of steel. It is believed that this piece of apparatus should be made of acid-resisting material or should be eliminated entirely.

As may be noted from the table, a system similar to this has been installed in the Crawford Ave. station.

Another interesting acid neutralizing system, also described in the 1926 N. E. L. A. Feed Water Treatment report, was installed in a plant of the Dallas Power and Light Co. This company had experienced severe trouble with embrittlement of the steel in the boilers and, to prevent a recurrence of the trouble in the new drums that had been installed, it was decided to keep the concentration of carbonates below a certain point and also to maintain the sodium sulphate at 3½ times that amount. This required that carbonates be removed and sulphates added. Two ways of doing this were considered and treatment with sulphuric acid was found most effective.

In this particular case it was decided to put the water directly into the feed-water heater but in working out a method the question of how much acid to feed came up. To avoid trouble with the heater and feed pumps and piping it was essential that the boiler water be always slightly alkaline. Since the amount of carbonates in the feed water seldom exceeded 1½ parts per 100,000 and, since 2/3 of this had to be neutralized, it was necessary to develop a simple, quick and positive test, which would indicate the presence of ½ part of carbonate per 100,000. This was difficult.

After several plans it was finally decided to introduce the caustic water from the boilers into the boiler feed water. This would increase the total solids in the boiler feed but would not increase the concentration in the boilers. It was obvious that, if enough of the caustic water was added to the boiler feed to give it 50 parts causticity per 1,000,000 considerably more acid could be added safely and a positive phenolphthalein test could be used as a control.

A small pipe was tapped into the blowoff line from each boiler ahead of the blowoff valve and run to a common header which joined the discharge of an ejector arranged for feeding the acid between the ejector and the feed water heater. In this manner acid is neutralized by the boiler water before it enters the heater and the only equipment which ever contains an acid water is the ejector and associated piping. To control the flow of boiler water it was necessary only to connect a pressure gage to the common blowoff header with a valve ahead of it to maintain the pressure required.

This equipment has been in use for over six months and has been highly effective in maintaining the desired sulphate-carbonate ratio. It is not claimed, however, that this is a cure for caustic embrittlement or even that there is or is not such a thing as caustic embrittlement. All that is known is that something in the

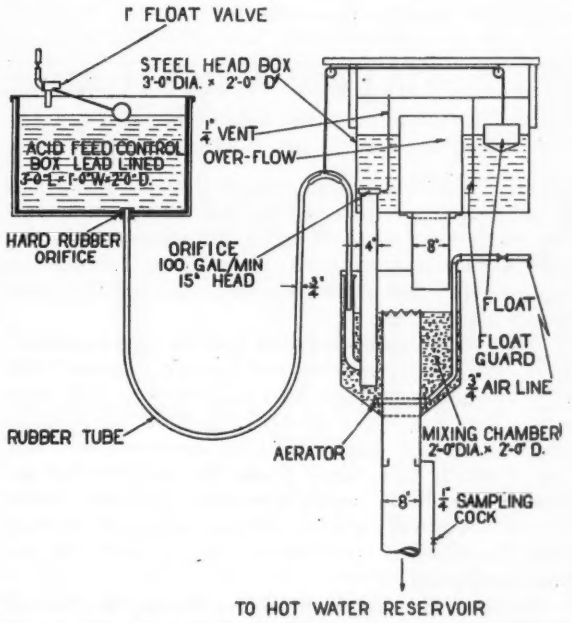


FIG. 2. DETAILS OF ACID FEEDING EQUIPMENT AT CALUMET STATION

operating conditions tended to make the steel become brittle. Because of this embrittling action it had been necessary to junk four boilers of 5200 sq. ft. each and to install new drums on three others. So it was agreed that everything should be done to prevent a recurrence of the trouble and, since the best authorities claim that there will be no embrittlement if the correct carbonate-sulphate ratio is maintained, the acid treatment was adopted.

As is evident from the table, the lime-soda ash method of treatment is popular and is widely used. The assertion has been made, however, that this method of treatment is not as successful at high boiler pressures as at low pressures and the use of tri-sodium phosphate has been advocated as a substitute for sodium carbonate. It is claimed that it does not dissociate to form sodium hydrate to the same extent as does sodium carbonate. The dissociation of sodium carbonate into sodium hydrate and carbon dioxide takes place in boiler water at high temperatures and pressures according to the following equation:

$$Na_2CO_3 + H_2O = 2\ Na\ OH + CO_2$$

The CO_2 passes off with the steam and the sodium hydrate, when the water is low in sulphates, as has been stated previously, causes embrittlement. The superiority of tri-sodium phosphate in this respect is not generally admitted, however, and, from a study of the stations under discussion, it does not appear to be in use to any great extent.

Zeolite systems for treating feed water are used in all types and sizes of modern power stations. The zeolite softener in use today is essentially unchanged from the original design but a number of improvements have been made, which increase the effectiveness of its operation. Improvements have been made in the salt-dissolving equipment, which permit the use of a cheap, common run-of-mine salt. The brine saturators are now so designed as to combine rapid dissolving of the salt, removal of dirt present in such salt and ready disposal of this dirt from the dissolving tank.

Practice in Feed Water Heating

The Regenerative Cycle Is Being Used in Most of the Modern Stations

FEED WATER heating in most of the larger central stations is accomplished by the use of multi-stage feed water heaters operating on the regenerative cycle. This method of heating has many advantages and, as may be noted from the tabulation, nearly all of the stations considered use it.

Temperatures and pressures used in the regenerative cycle vary widely, however, and the figures given in the table are not to be considered conclusive or even accurate. They are listed primarily to show the wide divergence between them. Accurate data were very difficult to obtain, as in many plants the temperatures and pressures are by no means constant. They vary widely with different loads and on different units and, in many cases, are changed from time to time to meet with new conditions arising.

The actual arrangement of heaters and the number of stages employed are also different in each station and it is difficult to classify the data obtained on the plants considered in this survey. In a survey conducted by the N. E. L. A. some time ago in plants, the construction of which was started not earlier than the spring of 1923, it was found that 53 per cent of the stations employed 3-stage heating. The average number of heaters used was 2.8 and the average temperature of the water leaving the last heater was 274 deg. F. The

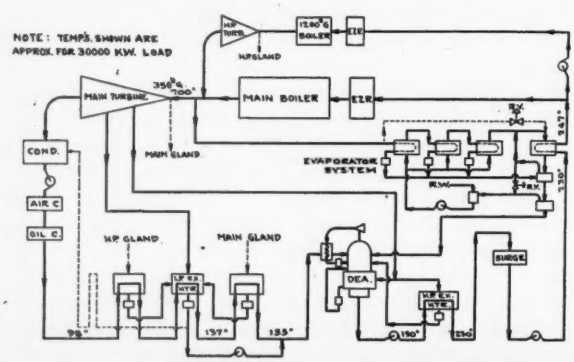


FIG. 1. HEAT BALANCE DIAGRAM, EDGAR STATION

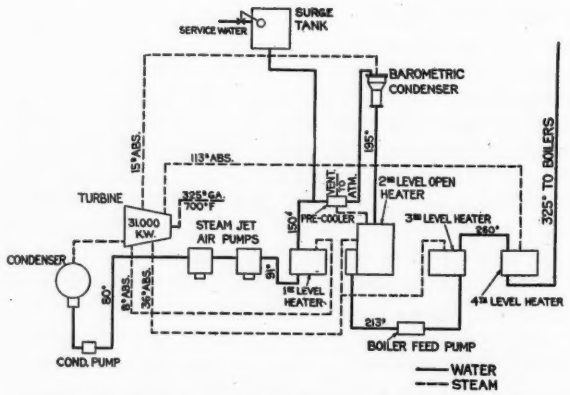


FIG. 2. HEAT BALANCE DIAGRAM FOR KEARNY

average temperature of the water entering the economizer was 246 deg. F., the average temperature entering the boiler without economizer 290 deg. F. and with economizer 325 deg. F.

Extraction heaters in use are mostly of the closed multiple pass type. These are, however, in many cases, used in combination with open deaerating type heaters. Closed heaters generally seem to be vented either to a lower level heater or to a lower stage of the turbine,

DATA ON BOILER FEED PUMPS

PLANT	NO. OF PUMPS	NO. OF STAGES	CAPACITY	HEAD-LB.	DRIVE
COLUMBIA	6	6	4-400 G.P.M. 2-500 G.P.M.	680 680	MOTOR TURBINE
CRAWFORD	2 1 1 1 2	1 1 4 4 1	500,000 #PER HR. 900 G.P.M. 800 .. 900 .. 900 ..	700 675 675 675 675	MOTOR TURBINE MOTOR TURBINE
PHILO	2 2	1 6	750 750	650 650	TURBINE MOTOR
TRENTON CHANNEL		6	1300	1090 FT.	
RICHMOND	4 2	6 6	1250 1600		MOTOR TURBINE
KEARNY	5	5	1500	1125	3 MOTOR 2 TURB.
AVON	3		1250	500	TURBINE
SOMERSET	3 1		800 500	440	MOTOR TURBINE
NARRAGANSETT	1 1 1	6 5 1	1000 1000 1000		MOTOR TURBINE
EDGAR	4	4	800		3 MOTOR 1 TURB.
LONG BEACH	4	5	1000		3 MOTOR 1 TURBINE
SEAL BEACH	1 2	4 6	1000		TURBINE MOTOR
SUSQUEHANNA	2 1	4 5	1000 350		
CAHOKIA	4	6	750		3 MOTOR 1 TURBINE
RIVERSIDE	3	1	1-700 2-300		MOTOR
WAUKEGAN	3	5	500	460	2 TURBINE 1 MOTOR
VALMONT	2 2		1000 G.P.M. 1000 G.P.M.		TURBINE MOTOR
HALES BAR	6 1 1	8 8 4	350 500 350		MOTOR MOTOR STEAM DRIVE
BIG SIOUX	2 1	6 4	600 600	740 990	MOTOR TURBINE
NEOSHO	1 1	5 4	350,000 #PER HR.		MOTOR TURBINE
DRESSER	3	4	2-1000 G.P.M. 1-1500 ..	425	2 MOTOR 1 TURBINE
EDGEWATER	2	4	1000	375	
BARBADOES	2		1000		
PINE GROVE	2 2		500 400		TURBINE MOTOR

either method apparently giving good results. The deaerator type also must be vented but, in this case, the escaping vapor is condensed by the incoming cold water, irrespective of whether the pressure in the deaerator is below atmospheric pressure and a steam ejector has to be used or whether it is above atmospheric pressure and no ejector is needed. This precaution is necessary not only to conserve the heat in the escaping steam but also to reduce the amount of makeup to a minimum.

As stated previously, the layouts of the feed water systems in the various stations vary widely and, while no attempt will be made to show the arrangement in all the stations listed, a few of the principal ones are here shown. Figure 1 shows the system used at Edgar. The heat in the air cooler and oil cooler is first absorbed by the condensate, after which the condensate passes through the low pressure heater, from there to the deaerator and then to the high pressure heater. The evaporator is supplied with high pressure steam, the vapor being absorbed after the condensate leaves the high pressure heater and before it enters the economizer. The steam used for deaerating is taken from the line into the second level heater.

The system used at Kearny is shown in Fig. 2. The turbine units are arranged for bleeding at four points. No evaporators are used. A deaerating type heater is installed which takes the place of a second level heater. If necessary, additional steam can be bled from the third level heater to raise the temperature in the deaerating heater. Steam from the second bleeding point is absorbed in a barometric condenser located high enough above the deaerating heater to permit the temperature in the heater being raised above that of the second bleeding point and still allow the barometric condenser to function satisfactorily.

Boiler Feed Pumps

Practice in regard to the boiler feed pumps used in central stations is shown in the table. Here too, it will be noted, practice varies widely according to conditions existing in the plant. The use of multi-stage pumps predominates but there are quite a few cases where the single stage high pressure pump is installed. The motor drive also predominates but for emergency uses there is always at least one turbine driven unit installed.

Economizers Developed to Meet High Pressures

Steel Tubes with Protected Surfaces Are Outstanding Features of Economizer Development

CONSIDERABLE change has taken place during the past few years in economizer practice. Not long ago it was thought that cast iron was the only logical metal for use in economizers. Today, however, steel tubes are used extensively, especially where they are subjected to high pressures. Group arrangements have given way almost entirely to the unit type, which, in addition to other advantages, permits locating the economizer within the boiler setting instead of in the breeching, though the latter location is still common. Another growing tendency is to employ the rear or low temperature section of the boiler to raise the temperature of the feed water on its way to the boiler proper. Again, due to an increasing tendency to preheat the air, used in the combustion of the fuel, by means of the flue gas, another factor has entered which influences not only the size of the economizer and its location but, in some cases, the preheater has displaced the economizer entirely.

Economizers of the cast-iron type are invariably placed in the breeching between the boiler and the stack, which location is almost essential, due to the scraping mechanism required for keeping the tubes free of soot. Steel tube economizers are not limited as to location, as they can be arranged as an integral part of the boiler, located within the boiler setting or in the breeching. Where the water temperature entering the economizer is low some protection against corrosion is provided. One make has the tubes covered with cast-iron rings which not only serve as a protection against corrosion but increase the heating surface exposed to the gases. Another make has the tubes covered with a thin coating of lead to prevent corrosive action.

Although in some cases, due to plant layout, the water flow is in the same general direction as the gases or directly across the gas stream, the tendency today is distinctly towards the counterflow arrangement wherever possible.

Ratio of Boiler Heating Surface to Economizer Surface

Just what the ratio between the economizer surface and the water heating surface in the boiler should be is dependent upon several features of the installation. The expected load upon the boiler, the steam pressure carried, the relative size of the superheater, the amount of reheat surface in the boiler, the kind of fuel to be burned and the installation of an air preheater must all be considered when determining the size of the economizer.

Inspection of the accompanying table will show that the ratio varies, for economizers that are not an integral part of the boiler, from 38 per cent to 76.3 per cent. An analysis of data given, however, reveals that the plants using air preheaters and those where the entering feed water is high have a lower percentage of economizer surface. Those having a high percentage of economizer surface are evidently designed with the intention of arranging the entire heating surface so that it will be subjected to a sufficiently high temperature difference to permit every part of it to do a proper amount of work. Integral type economizers have a lower ratio, varying from 23.6 per cent to 47.9.

Modern practice, according to some authorities, calls for ratios of gas to water weights varying from 1.3 to 1.5. With such ratios the loss in temperature on the gas side is about three times the increase in temperature of the water. In the plants analyzed, however, the gas temperature drop is not so great as will be shown later. The work done per square foot of the economizer is, therefore, controlled by the inlet temperatures of the

ECONOMIZERS

PLANT	HEATING SURFACE PER BOILER SQ.FT.	TYPE OF ECONOMIZER	ECONOM. SURFACE SQ. FT.	ECON. SURF. % OF BOILER SURFACE	LOCATION	TEMPERATURES WATER IN	TEMPERATURES WATER OUT	TEMPERATURES GAS IN	TEMPERATURES GAS OUT	
COLUMBIA	15,110	STEEL COUNTERFLOW	7300	48	REAR OF BOILER SETTING	215	328	562	349	ALSO AIR PREHEATERS
CRAWFORD	SUPERHT. 16,615 RENT. 6000 WATER 14,000 REHT.	STEEL	11,000 7,500	66.3 125.	BREECHING	210 TO 350	340 TO 425	600 TO 650	275 TO 325	ALSO AIR PREHEATERS
PHILO	14,086	STEEL	8837	62.7	REAR OF BOILER SETTING	216	326	595	346	ALSO AIR HEATER
TRENTON CHANNEL	29,087	STEEL	18,984	65	BREECHING	210	314	622	335	TEMPERATURES AT 333⅓% RATING
RICHMOND	15,698	STEEL INTEGRAL	7516	47.9	REAR TUBES OF BOILER	290				ALSO AIR HEATERS
KEARNY					NONE					
AVON	30,600	STEEL 2 PER BOILER	21,120	69	BREECHING	200		485-575 715-810		100-200-300-350 = PERCENT RATING FOR WHICH GAS TEMPERATURES ARE GIVEN
SOMERSET	14,920	STEEL	9288	62	BREECHING	239	344	582	357	
NARRAGANSETT					AIR PREHEATERS					
EDGAR	350 = 14,743 1200 = 15,732	STEEL HORIZONTAL COUNTERFLOW	12,096 11,091	61 70	BREECHING					CLEAN WITH SOOT BLOWERS AT 150 LB. STEAM
LONG BEACH	15,000 14,916	STEEL	11,448 6,804	76.3 46.3	REAR OF BOILER SETTING	280 336	350 368			
SEAL BEACH					AIR PREHEATERS					
SUSQUEHANNA	14,770	STEEL	7760 7600	52.5 51.5	BREECHING	212	320	520	300	
CAHOKIA					NONE					AIR PREHEATERS ON 2 BOILERS
RIVERSIDE	10,438	STEEL	6480	62	BREECHING	205	298			CLEANING DONE WITH SOOT BLOWERS AND WASHING
WAUKEGAN	14,086	STEEL	8837 8037	62.7 51.3	BREECHING	190 190	305 300	550 570	300 315	ALSO AIR HEATER
VALMONT	10,845	STEEL INTEGRAL	2474	24	REAR TUBES OF BOILER	300				
HALES BAR	10,750	CAST IRON VERTICAL	7470	69.6	BREECHING	175	285	650	380	CLEAN WITH SOOT BLOWERS-PRES. 250 LB.-ALSO AIR HEATERS
BIG SIOUX	11,124	STEEL	4215	38	BREECHING	230	305			
NEOSHO	12,000	STEEL INTEGRAL	3245	27	REAR TUBES OF BOILER	225				
DRESSER					NONE					
EDGEWATER	14,643	STEEL INTEGRAL	3463	23.6	REAR TUBES OF BOILER	205	255		470	CLEANED BY DRILLING
BARBADOES					NONE					
PINE GROVE					NONE					
IRON MT.					NONE					
FORDSON					AIR PREHEATER					
BROTHERHOOD OF L.E. BLDG.					NONE					
BETTENDORF					NONE					
BAYONNE					NONE					

gas and water. Tests conducted on steel tube counterflow economizers indicate that a heat transfer of 5 to 5.25 B.t.u. per square foot per degree mean temperature difference can be expected. It is estimated that with air infiltration and radiation losses reduced to a minimum a reduction of approximately 40 deg F. in exit gas temperature under ordinary conditions of combustion, is equivalent to 1 per cent increase in the efficiency of the boiler unit.

Although most economizers are located in the breeching between the boiler and the stack there is a growing tendency to place them within the boiler setting or to build an economizer section in the boiler. This change has come with the development of steel tube economizers which do not require a scraping mechanism and may be subjected to the pressure carried in the boiler. Figure 1 shows the economizer locations in the plants analyzed. It will be noted that in all cases where both ecenomizers and air preheaters are installed the gases pass first through the economizer.

In the Delray plant the breeching and dampers are so arranged that two economizers may be used to serve three boilers. This additional boiler gives a flexibility of service and a net gain in heat absorbed but is not very desirable from the standpoint of operation, as a change in draft on one boiler affects the other two also. This will be appreciated upon studying Fig. 2. Another arrangement called for in some plants is for up-flow gas

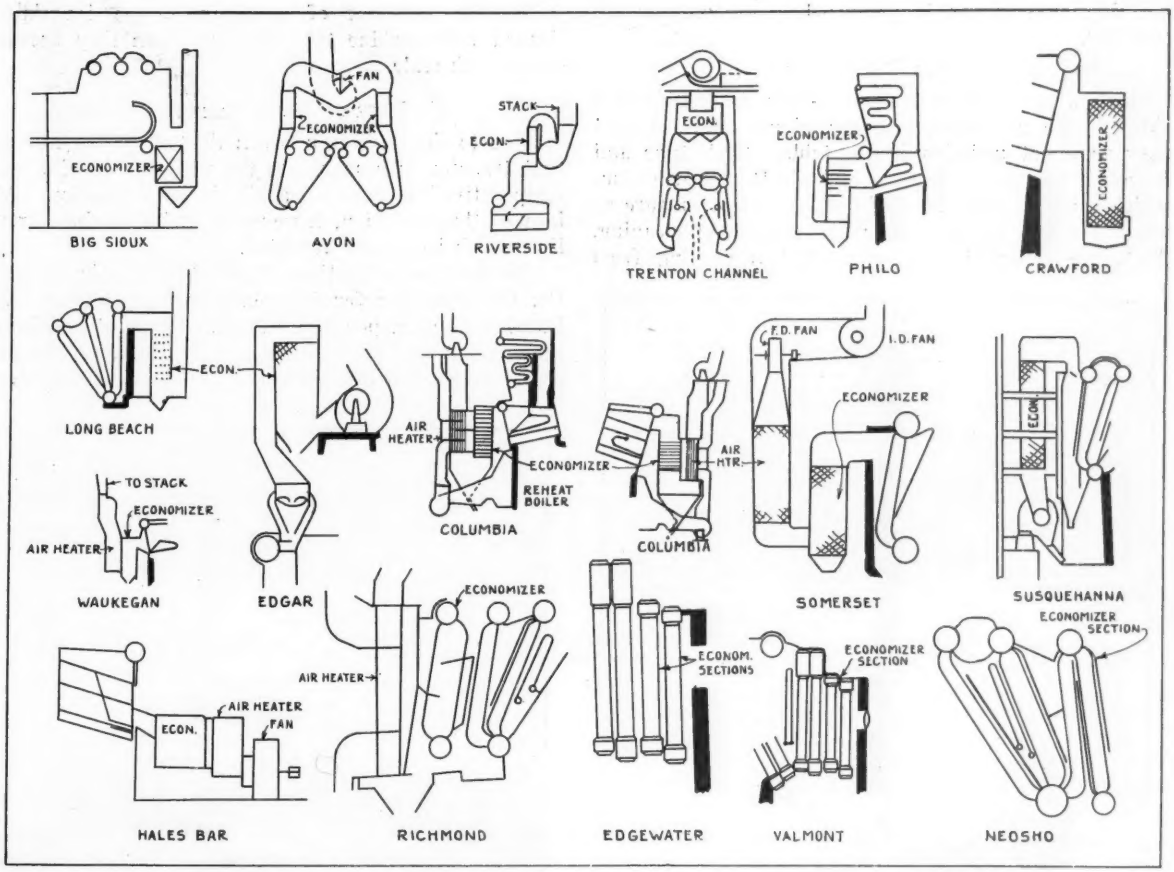


FIG. 1. SECTIONS OF VARIOUS BOILER INSTALLATIONS SHOWING ECONOMIZER LOCATIONS

and down-flow water. This arrangement is probably the least expensive to install but requires careful proportioning to give proper velocity of water which will prevent vapor pockets.

Temperature Range

Water inlet temperature to the economizer is governed largely by the heat balance employed in the plant. The average, however, is in the neighborhood of 210 deg. F. This is sufficiently high to prevent condensation on the gas side of the heating surface and at the same time low enough to give considerable temperature drop between the exit gas and the entering water.

Comparison of the inlet and outlet temperatures given in the table will indicate that the water in passing through the economizer is raised about 100 to 110 deg. While data on the drop in temperature of the gas through the economizer were not available in all cases, it is apparent from the figures given that the average decrease in gas temperature is about 2.25 times the rise in water temperature. It is also evident that exit gas temperatures are about 100 deg. above the water inlet temperatures and that stack temperatures of 300 to

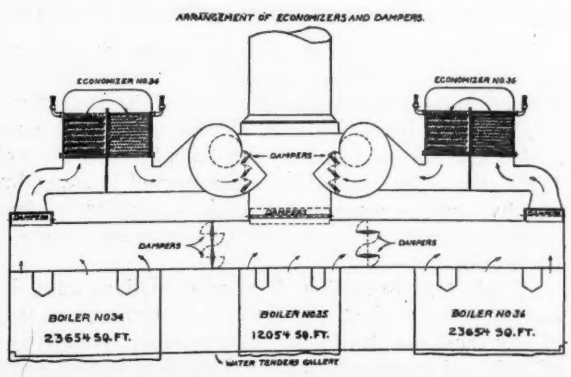


FIG. 2. BREECHING AND DAMPER ARRANGEMENT BY MEANS OF WHICH TWO ECONOMIZERS SERVE THREE BOILERS

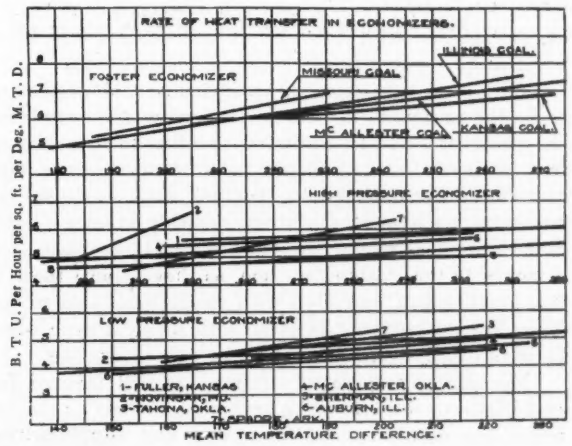
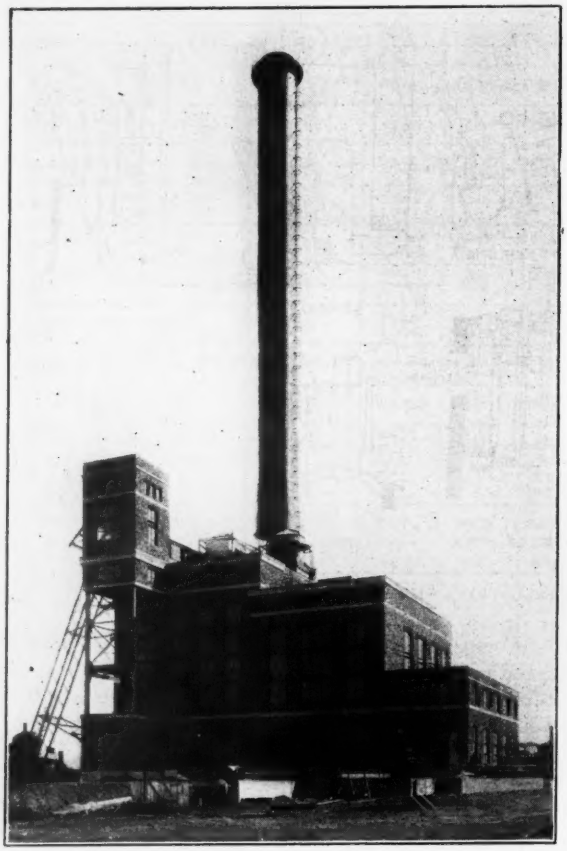


FIG. 3. VARIATION OF HEAT TRANSFER IN ECONOMIZERS WITH VARIOUS GRADES OF MIDDLE WEST COALS

350 deg. are common in plants where economizers are installed.

Draft Resistance

So few figures were available on the draft resistance through the economizers in the plants analyzed that they were not included in the table. Each type and make of economizer has its own draft characteristics which vary with the kind of coal used, temperature of the water and the frequency and method of cleaning. Tests are recorded showing draft loss varying from



BARBADOES ISLAND STATION

2.5 to 4 in. of water in a steel tube economizer of 12,000 sq. ft. surface with 4500 lb. of gas passing per hour per square foot of free area.

With steel tube economizers steam soot blowers seem to be the preferred devices for removing the soot from the gas surfaces. In ordinary practice these are used once a day. In some plants the soot blowers are supplemented by washing the surface with a stream of water from a hose varying from monthly to once a year. Some operators prefer the hand steam lance used once a month to the washing method, as they believe there is less likelihood of corrosion with steam than with water. They are particularly favored with integral type economizers that have no protecting surface or coating.

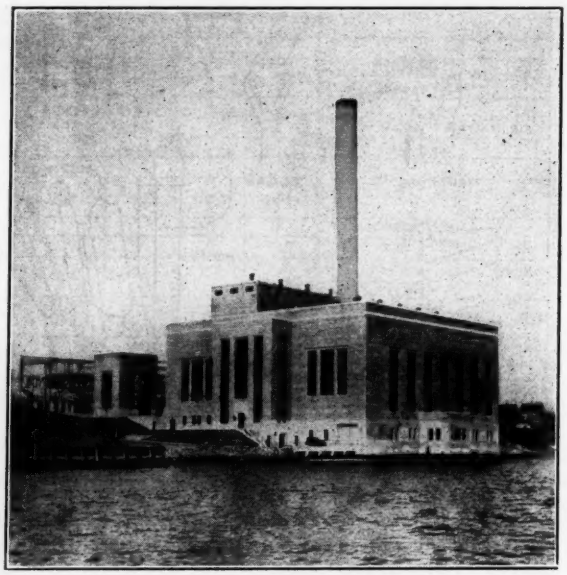
Mechanically operated scrapers are still favored for cast-iron economizers, being kept continuously in motion while the economizer is in service and supplemented with hand scraping to clean the surfaces thoroughly when the economizer is shut down.

Interior surfaces of economizers are invariably cleaned with turbine tube cleaners when they become coated with scale.

Rate of Heat Transfer

Due to the many conditions that affect the rate of heat transfer in economizers the variation is wide and comparative data was not available for tabulation. An idea of this variation, however, may be obtained from lists which have been reported.

In the Chester station of the Philadelphia Electric Co. the heat transfer in economizers runs from 3.28 B.t.u. per sq. ft. per deg. F. mean temperature difference at 120 per cent rating to 6.24 B.t.u. at 300 per cent. In the Cleveland Electric Illuminating Co. plant



SOMERSET STATION

the heat transfer ranges from 1.5 B.t.u. at 800 lb. gas per hr. per sq. ft. of free area to 5.5 B.t.u. at 4200 lb. gas.

How variation in the kind of coal used affects the heat transfer in economizers is well illustrated by the curves shown in Fig. 3, which were reported to the N. E. L. A. by the Kansas City Power & Light Co.

Secretary Hoover on Electrical Progress

"The application of electrical power to home use has received enormous expansion." Said Secretary Herbert Hoover in the annual report of the Department of Commerce made recently. "The number of homes served has increased in six years from 5,700,000 to over 15,000,000. The number of farms served is expanding rapidly, and in some states, such as California, farm electrification far exceeds that in any other locality in the world.

"This transformation, it may be said at once, has increased the productivity of our workmen beyond those of any other country; it contributes to our maintenance of high real wages and to the reduction of human sweat; it relieves the homemaker of many irksome tasks and adds immeasurably to home comforts."

Boilers and Superheaters Show Improvements

HIGHER PRESSURES AND TEMPERATURES, LARGER BOILERS, HIGHER RATINGS, REHEAT BOILERS, WATERWALLS AND IMPROVED APPURTENANCES COMBINE TO MAKE PROGRESS IN THIS FIELD NOTABLE. BY ALEX D. BAILEY*

DECIDED changes have been witnessed in boiler and superheater design and operation in the past five years. Boiler capacities have continued to increase both as regards size of installation and capacity developed per unit of heating surface.

Improvements in furnaces and firing systems have resulted in driving boiler heating surface at higher rates, and within the last year or two installations fired with pulverized coal, as well as others fired with stokers, have given phenomenal performance, both in regard to rating and efficiency. There has been a consistent increase in the rate at which the boilers of each new installation are being operated. While this has increased the importance of economizers and preheaters, efficiencies have been maintained or even improved, and the desired end, in that is, more steam generating capacity for the invested dollar has been achieved.

NOTICEABLE ABSENCE OF TROUBLE CHARACTERIZES HIGH-PRESSURE INSTALLATIONS

Steam pressures and temperatures have also increased and the successful performance of the newer installations in this class have removed any fear which may have been entertained regarding their commercial success. There are now several installations operating at 600 lb. pressure and 725 deg. F., giving a good account of themselves, while the two notable 1200-lb. installations were put into, and have continued, in service with a noticeable absence of trouble. Steam temperatures of 725 deg. F. have become standard practice and temperatures still higher are being considered. The numerous studies now going on regarding the effect of high temperatures on metals will determine what metals are suitable for this service and just how much this temperature can be safely increased.

*Superintendent of Generating Stations, Commonwealth Edison Co., Chicago, Ill.

HEATING SURFACE AND STEAMING CAPACITY INCREASES ARE NOTEWORTHY

There has been a notable increase in the size of individual boiler installations in regard to heating surfaces as well as steaming capacity and Detroit has again taken the lead. While the boilers at the Beacon Street heating plant of the Detroit Edison Co. are not operated at so called high pressure, they are noteworthy because of their size and steaming capacity.

This change in pressure has resulted in certain changes in boiler design, principally in the size of tubes and drums. The former have been reduced from four to two or three inches while the drums of necessity have been reduced in diameter until the water content is relatively small compared to the steam output. Steam releasing surfaces have been reduced as capacity has been increased and as the densities of the steam and of the water have approached the same value.

HEAVY STEEL CASTINGS OFFER PROBLEMS FOR MANUFACTURERS

One of the major sources of trouble resulting from higher steam pressure and temperature has been leaky steel castings. Manufacturers are doubtless endeavoring to remedy this defect as it is very evident that methods and shop practices followed in the casting of these fittings be improved and that some commercial method of testing these castings be developed to forestall so much trouble in service. While forged fittings are being supplied in the smaller sizes, no universal substitute for larger steel castings has as yet been developed and the users are looking to the manufacturers to remedy this condition.

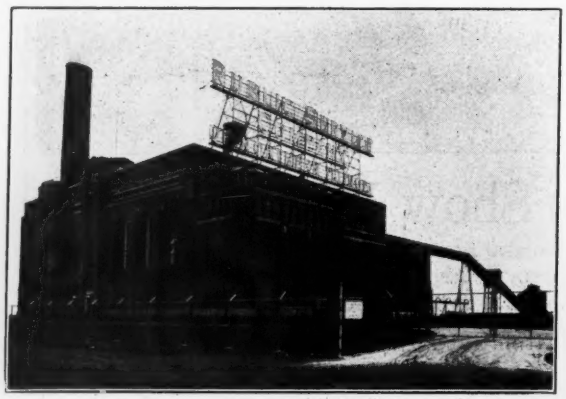
Because of higher ratings it has been necessary to give more consideration to proper tube spacing and arrangement to prevent slagging of the gas passages and

to facilitate cleaning. The flue gas opening into the boiler itself has also been changed and the entire tube length in the first pass opened to the furnace to give the unrestricted effect of radiant heat.

Much Anticipated Reheat Boiler Trouble Did Not Materialize

Inter-heat or reheat boilers which have been installed in several recent 600-lb. installations have justified the confidence and expectations of their designers and owners. Anticipated troubles have been well taken care of or it has been found that they did not develop. Their operation has been simple and not attended by any unusual care or precautions.

So far as superheaters are concerned, there has been a general tendency to move these nearer the furnace in



WAUKEGAN STATION

order to get the required steam temperature. This, of course, applies only to convection type superheaters which previously were located above the boiler tube bank. When brought down to an inter-deck position they are sometimes found in series with radiant superheaters in the furnace walls. In some cases all the superheating is done with radiant superheaters and in one case all superheating and reheating is accomplished with radiant superheaters. With this type of equipment the control of steam temperature is reported to be very exact.

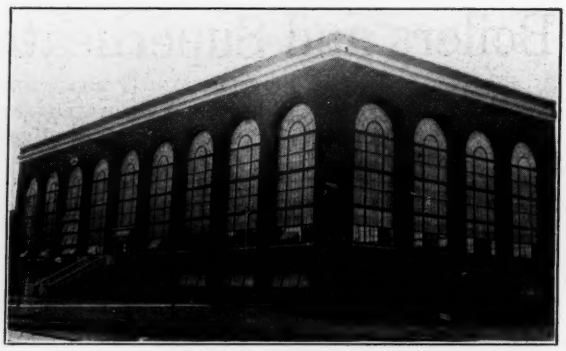
Water Cooled Walls Have Been Remarkably Successful

Water cooling of furnace walls, wholly or in part, has been uniformly successful and this feature of boiler and furnace construction has become almost universal in some form or other. This type of construction, which was originally designed to reduce furnace maintenance, has developed into a most important heat absorbing medium and its benefits have been two fold. Refractories were not able to stand the high temperatures and severe service due to the high capacities everywhere sought for and obtained. This was particularly true with coals having a low temperature slagging ash. The water cooled wall either protected the refractory from the high temperatures and molten ash or removed the refractory altogether. Second, the water-cooled wall which in some manner or other is generally connected with the boiler proper has justified the most optimistic promises of its advocates and as a heat absorbing medium has been a great success. It has in a measure offset the increase in furnace temperature due to the advent of preheated air, but there has apparently been no deleterious effect on furnace performance.

Water screens continue to be used for pulverized fuel furnaces, generally connected into the boiler circulation. In one installation however this part of the installation is a separate boiler, having its own drum and other boiler appurtenances.

Importance of Feed Water Increases With Higher Boiler Ratings

Higher operating ratings and increasing rates of heat transfer have made clean boiler feed water an absolute necessity. Mud or scale-forming matter in any form can no longer be tolerated. The effect has gone clear back to the condensing equipment of the prime mover with the reduction of leakage to an absolute minimum. Evaporators are being used more and more for the purification of any necessary make-up. The condition of the boiler water also has a marked effect on the carrying over of moisture with the steam at high ratings.



THE BETTENDORF PLANT

At the high pressures and temperatures, safety valves which the pessimists and doubters predicted would give no end of trouble and which could never be kept tight have given surprisingly good service and seem to keep tight under the severe conditions imposed. There has been a change in other boiler appurtenances as well. The gage glass for high pressures resembles in no way its predecessor but is made up of heavy flat glasses mounted in a heavy steel case, the glass being protected on its inner face with mica to prevent etching.

Differential Pressure Regulator Relieves Feed Water Regulator of Some Responsibility

Feed water regulators continue to do their job though their work has been ameliorated in some cases by the addition of a differential pressure regulator, put in the feed lines to the individual boilers immediately ahead of the feed regulator. Under this condition the feed regulator merely controls water level and it does this better than when it also has to take care of pressure fluctuations which are more severe as pressures and ratings increase.

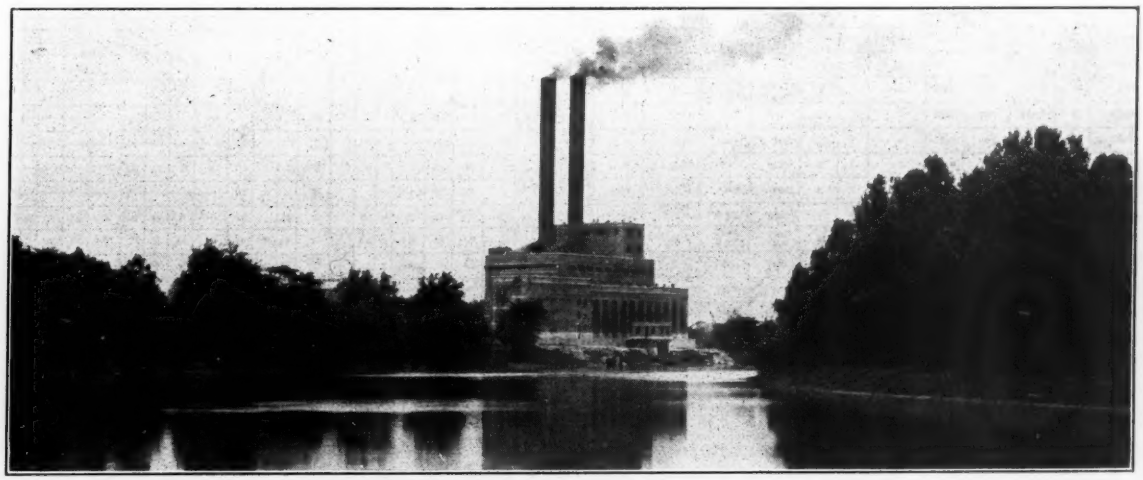
In looking back over the changes in boiler and furnace design and construction, it can doubtless be said that progress in this branch of power station equipment has probably been more pronounced than in any other.

Boiler Pressures Continue to Increase

HIGHER PRESSURES AND RATINGS BRING OUT NEW DESIGNS AND PROBLEMS. REHEAT AND WATER SCREEN BOILERS USED IN NEW STATIONS

BOILER SIZES in the neighborhood of 25,000 sq. ft. and over are not common, boiler development extending to higher ratings rather than increased surfaces. Evaporation rates of 11 lb. per sq. ft. of heating surface are reached in the later units for normal service with correspondingly high peak capacities for short periods. Trenton Channel, Kearny, Avon, Seal Beach and Fordson come within this class and apparently no one type is better adapted for these large sizes as the five plants represent four types of boilers.

Considering only installations which have been made and upon which data are available, the most decided trend has been toward higher pressures. Two very high pressure units, one 1200 and one 1295 lb. per sq. in., are in service with very satisfactory reports of operation. Although this represents practice somewhat beyond proven ground, pressures of between 600 and 700 lb. are well established for large central stations. From here the pressures range downward to 400 in more designs, 300 in the older stations and 200 in the industrials. In the latter field there is, however, a decided impetus to the use of 400 or 450 lb. boilers to be combined with high back pressure turbines.



DRESSER STATION ON THE WABASH RIVER

EUROPEAN PRESSURES SOMEWHAT HIGHER THAN THOSE USED HERE

European practice runs somewhat higher than that followed in this country reaching as high as 1765 lb. and 840 to 930 deg. F. Several plants are either under construction or have been proposed, the most recent one being an industrial plant with units designed to produce 130,000 lb. of steam per hour. Experimental work is even being carried on at the critical pressure of 3300 lb.

Pressures of over 650 or 700 lb. have made it necessary to develop an entire new line of fittings, valves and gaskets and furthermore has resulted in a great deal of valuable research regarding the properties of metals at high temperatures. Plates necessary for such high pressures are so thick that drums have to be forged from solid billets, drilled out and the nozzle or flange forged on. Nickel steel containing from 3 to 5 per cent nickel has been found to give best results at present but it is hoped that further research may develop an alloy even more suitable for these extraordinary conditions.

EVAPORATORS DO NOT ELIMINATE BOILER CONCENTRATION PROBLEM

Drums must of necessity be small, resulting in comparative small water storage capacities so that, unless the turbine operates under conditions of steady load, some kind of an accumulator or external hot water storage tank may be necessary. In addition, there is the ever present difficulty of boiler concentration to deal with because, in spite of evaporators, concentration will continue to build up until some method of eliminating condenser leakage is developed.

New types of boilers to meet these unusual conditions have been proposed and are being developed. It is practically certain that the future will see great advances and important developments in this field. What these advances will be cannot be predicted but the trend of investigation at present is toward the use of small diameter tubes, which can be built to withstand high pressures in a boiler built entirely around the furnace. Several boilers of this type are being installed.

In both bent tube and straight tube types there is a tendency toward the use of larger or more widely spaced tubes directly over the fire, so as to expose the maximum surface to radiant heat. The first two rows are commonly placed one above the other, rather than staggered, in order to increase this effect and facilitate cleaning. This is well illustrated on the boiler tube arrangement shown in the following article dealing with superheater development. Where these tubes have had a tendency to slag up, the problem of cleaning has been successfully solved by the use of a water lance.

BOILER DATA

STATION	NO. OF MAIN BOILER	BOILER HEATING SURFACE	WATER SCREEN SURFACE	ABS. PRES.	TYPE ③	BAFFLING PASSES	BAFFLING ARRANGEMENT ②	FURNACE VOL. CU. FT.	FURNACE VOL. CU.FT. PER SQ.FT. W.S.	FUEL	FD. WATER CONT. METHOD	FD. WATER CONT. NO. PER BLR.	SOOT BLOWING METHOD	SOOT BLOWING NO. EL. PER BLR.	TUBES WIDE	TUBES HIGH OR DEEP	DRUMS CROSS OR LONG	DRUMS NO	DRUMS STEAM DIA.	DRUMS STEAM LGT.	TUBES FIRST BANK ROWS	TUBES FIRST BANK DIA.	TUBES FIRST BANK BWG	TUBES FIRST BANK LGTH	TUBES SECOND BANK ROWS	TUBES SECOND BANK DIA.	TUBES SECOND BANK BWG	TUBES SECOND BANK LGT.	TUBES THIRD BANK ROWS	TUBES THIRD BANK DIA.	TUBES THIRD BANK BWG	TUBES THIRD BANK LGT.
COLUMBIA	6	15,110	NO	615	2	2	1	12,560	.833	PULV COAL	REGULATOR	1	MECHANICAL	26	36	15	C.	1	48	32'-10¼"	8	3¼	6	17	17	2	9	17				
CRAWFORD	12	16,615	NO	615	2	2	1	5710 6,200	.356 .373	COAL(STOKER)	R.	1	M.	20	40	25	C	1			8	3¼		15	17	2						
PHILO	6	19,086	NO	615	2	2	1	5,430	.387	C(S)	R.		M.		34	25	C	1														
TRENTON CHANNEL	8	29,087	1220	430	7	5	8	23,140	.83	P.C.	R.		M.				C	5	48		3¼											
RICHMOND	12	15,697	10-597 2-548	415	6	3	9	7,800	.48	C(S)	R.		M.				C	4	42		3¼				3¼				3¼			
KEARNY	12	23,600	NO	375	1	3	3	8865 10472	.380 .359	C(S)	R.	2	M.	22	48	20	C	1						21								
AVON	4	30,600	792	405	6	4	10	30,600	.988	P.C.	HAND	—	M.				C	6	43	34'												
SOMERSET	3	14,916	NO	390	6	3	9	12,900	.855	OIL	R.		M.	16			C	4														
NARRAGANSETT	2 2	18,755 17,084	1650	390	1	3	3	13,000	.636 .694	P.C.	R.		M.		36 36	20 18	C	1				4		22								
EDGAR	3	19,734	NO	375	1	3	3	9000	.456	C(S)	R.		M.		48	17	C	1			6	4		20	11	4		20				
LONG BEACH	11 4	15,000 14,918	NO 282	410	6	3	9	6900 5900	.427 .369	OIL & GAS	R.		M.		60	28	C	4			4	3¼	9		6	3¼	8		7	3¼	8	
SEAL BEACH	3	25,900	NO	400	1	3	3	10,375	.407	OIL & GAS	R.		M.		43	20	C	1	60	32'-9¼"	6	4		24	14	4		20				
SUSQUEHANNA	6	14,770	450	365	6	4	10	11,000	.723	P.C.	R.	2	M.	16			C	4	42 48			4				4		4				
CAHOKIA	18	18010	580	365	1	3	3	11,440 18,900	.615 .666	P.C.	R.	2	M.	18	36	20	C	1	60	33'-6"		4	7	20		4	7	20				
RIVERSIDE	4	10,438	NO	440	3	3	3	5,400	.518	C(S)	R.		M.		34	15	C	1	89	23'-3½"	15	3½	7	20								
WAUKEGAN	6	14086	NO	415	2	2	1	4,300 5,330	.306 .379	C(S)	R.		M.	22	34	25	C	1			8	3¼			17	2						
VALMONT	4	10,845	302	390	9	1	VERT.	8160	.733	P.C.	R.	2	M.		9	9 UNITS ①					124 TOT	3¼	8	18 19								
HALESBAR	3 2	10,750 10300	NO 125	390	1	2	2	33403 1-5178 1-5338	.317 .311 .333	C(S)	R.		M	6	25 37	18 78	C	1														
BIG SIOUX	4	11124	NO	370	6	4	10	7810	.702	P.C.	R.		M.				C	4			92	3½	8									
NEOSHO	3	12,000	NO	365	6	3	9	2-6185 1-6,358	.516 .532	C(S)	R.	2	M.	8			C	4														
DRESSER	8	17260	NO	365	1	3	3	4,014	.233	C(S)	R.	1	M.	18	36	20	C	1			14				6							
EDGEWATER	3	14,693	NO	315	9	1	VERT.	9015	.616	C(S)	R.		M.	10	12	5 UNITS ①					1260 TOTAL	3¼	9	18 19								
BARBADOES	3	16,800	NO	320	1	3	3	4470	.296	C(S)	R.	2	M.		48	24	C	1	84	26'	8	3	10	20	16	2	10	20				
PINE GROVE	6	7989	NO	315	4	3	3	2246	.281	C(S)	R.		M.		20	18	LONG	2			18	4	8	20								
IRON MT.	4	13,610	281	265	5	3	7	10,000	.720	INDUST. WASTE	R.		M.	8	33-38 42	22	C	4	36	13'-5"	7	3½		22	9	3	10	21	6	2½	11	20'-5"
FORDSON	6 2	26,970 26,970	NO 2430	265	8	3 3	6	16,000 22,500	.605 .762	P.C.	R.	2 4	M.		41	18	C	5	60	23'-10½"	7	3¼	10	21	6	3¼	10	18 4"	5	3¼	10	21'-6"
BROTHERHOOD OF L.E. BLDG	4	4120	NO	250	4	3	4	1,037	.252	C(S)	R		M.		16 17	11	LONG	2	36"	23'-11½"	82 2	4	8	20	9	9	9	20				
BETTENDORF	6	3085	NO	165	10	1	NO	←	WASTE	HEAT →	R.	1	HAND		—	—	—		78	20'		2½		20								
BAYONNE	8	10217	NO	195	9	4	5	2000	.196	C(S)	R.	1	M.	6	28	16	LONG	4	36"	21'	16	4	9	21								

NOTES ① 9-9-9-7-5-5 ② 12-12-12-10-8-6 ③ SEE OPPOSITE PAGE FOR BOILER AND BAFFLING SKETCHES

Entire First Rows of Tubes Put in First Pass

One, two, three, four and five passes are in general use, apparently more a function of the external conditions and equipment than of the boiler itself. As the regenerative cycle is extended and the feed water brought more nearly to the boiler temperature, the last or cooler passes of the boiler become of less use, eliminating the need of multi-passing and economizers and throwing the responsibility of proper flue gas cooling into the air preheater. In practically all of the later straight tube boilers the entire first row of tubes is thrown into the first pass regardless of whether two or three passes are utilized.

Mechanical soot blowers, sometimes using as high as 26 units per boiler, have been satisfactory in keeping the remaining tubes clean. Considerable development work has been done using compressed air in preference to steam for this purpose. Columbia uses air at 90 lb. It is to be used in another large station now nearing completion and is being tried in several industrial concerns. Its use is entirely satisfactory and cleaning effect good but comparative costs with steam operated elements are not yet available.

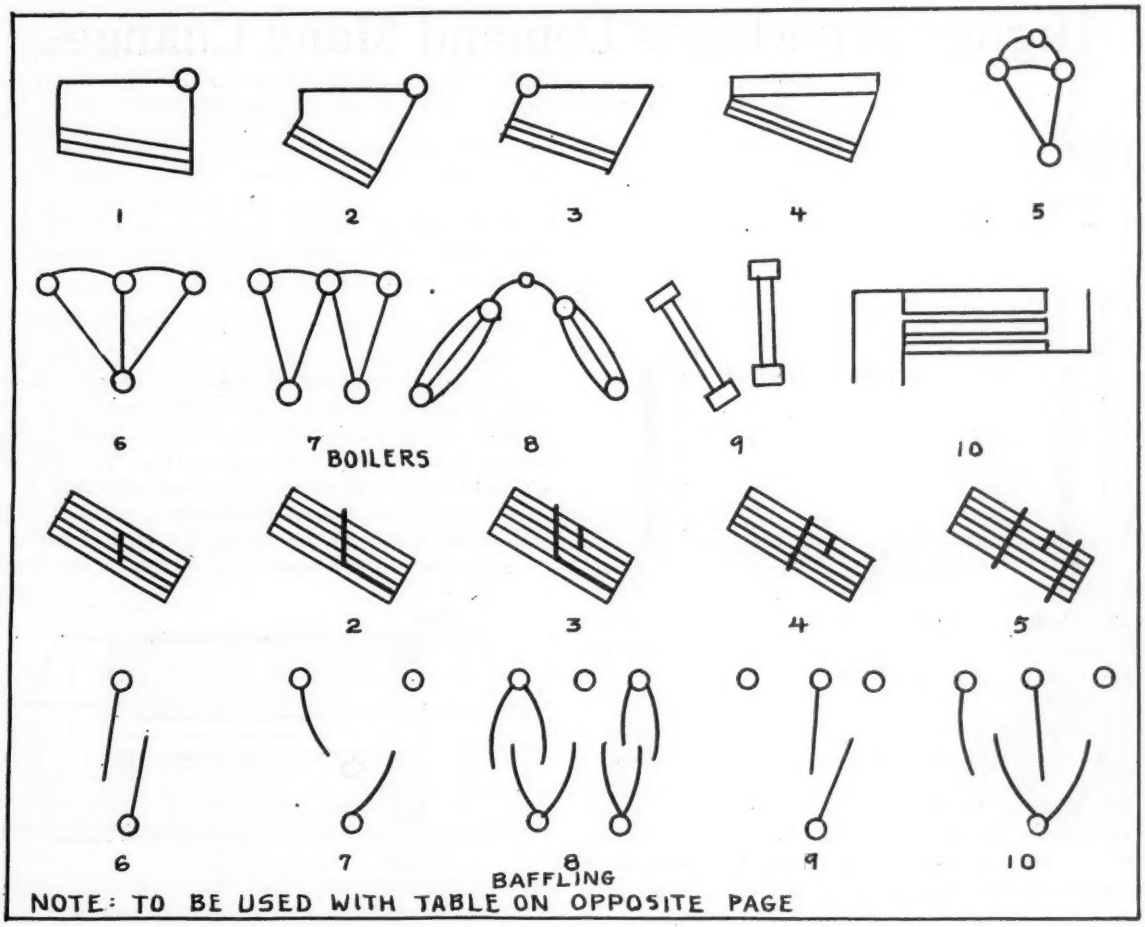
Steam bled from the low pressure turbine has been tried but is not entirely satisfactory due to the necessary long lines and corresponding amounts of condensation. High pressure steam reduced through a monel metal orifice to the desired pressure of about 200 lb. has proven to be the most satisfactory method of operation and is in general use.

Reheat Boilers Proved to Be Practical

Reheat boilers installed have been of the straight tube type but other types using live steam have been developed and offer decided advantages over the old type because of the absence of piping and decreased pressure losses. This is perhaps rightly called a re-superheater and is described in the superheater section following.

REHEAT BOILERS

STATION	NO REHEAT BOILER	BOILERS SERVED BY REHEAT NO	BOILERS SERVED BY REHEAT TOTAL M.H. SURF	BOILER SECTION PRES ABS.	BOILER SECTION TYPE	WATER HEATING SURFACE TUBES WIDE	WATER HEATING SURFACE TUBES HIGH	WATER HEATING SURFACE TUBE DIA.	WATER HEATING SURFACE BWG	WATER HEATING SURFACE SQ. FT.	CAPACITY LBS/HR.	CAPACITY LBS/SQ.FT.	SUPERHEATER SECTION SURFACE SQ. FT	SUPERHEATER SECTION SURFACE % W.H.S.	SUPERHEAT	TOTAL TEMP	% RATING	REHEAT SECTION PRES ABS	REHEAT SECTION TEMP IN	REHEAT SECTION TEMP OUT	REHEAT SECTION SURFACE SQ. FT.	REHEAT SECTION SURFACE % W.H.S.	REHEAT SECTION SURFACE % TOTAL W.H.S.	CAPACITY LBS/HR.	CAPACITY LBS/SQ.FT.	NO DRUM	
COLUMBIA	2	4	51,396	615	1					6,066			1,410	23.2	250	750		135	400	725	17,618	290	34.3			3	
CRAWFORD	2	5	72,467	615	1	40	8	3¼		6,007	96,500	16.05	1443	24.0	260	780		420	430	700	17458 16,124	291 268	24.1 22.3	480,000	28.6	3 3	
PHILO	2	4	33,167	615	1					5,031	75,000	14.90	1,432	29.6	225	725		150	460	725	11,158	222	33.6	310,000	27.9	3	
EDGAR	1	1	15,732	1215	2	80	22	3½ 2	#5 B.W.G. ⅞"	15,732			2,923	18.6	159	701	2.50	375	490	701	5,936	37.8	37.8				



MANY TYPES OF BOILERS AND BOILER BAFFLING IN USE INDICATES DIVERSITY OF CONDITIONS AND OPINIONS IN THIS FIELD

When reheat boilers were first contemplated it was but natural that they were developed along the lines of standard boilers, perhaps more in the nature of a separately fixed superheater with small surfaces to act as a screen giving protection from excessive temperatures. Practical operations of three stations for many months prove that the operating difficulties expected did not materialize. Forced shut-downs have been less than for standard units of the same stations and made necessary in every case by causes external to the reheat boiler itself.

At Crawford, Philo and Columbia firing is controlled by the temperature of the reheated steam. At Crawford stoker speeds are automatically controlled but in practical operation it has been found possible to maintain steady combustion rates over a wide range of load so that this control functions only at very light turbine loads.

Reheat Tubes Must Be Protected from Overheating

At Edgar reheat temperatures are regulated by means of a movable baffle. In all the plants, it has been found that reheat temperatures change comparatively slow so that even in case of the turbine dropping the entire load, there is sufficient time available to regulate furnace conditions by hand to protect the reheat tubes. This protection is afforded by air admission doors controlled either automatically or by remote control.

The reheat boilers, whose main function is to reheat the exhaust steam from the high pressure turbines, also produce steam. At Crawford both types of boilers are set over the same furnace, the reheat boiler being rated at 96,500 lb. of steam per hr. with a reheat capacity of 480,000 lb. per hr., while the standard boilers are rated at 150,000 lb. per hr. This is about 10 lb. per sq. ft. for the standard boilers, 16 lb. per sq. ft. for the steaming part of the reheat units and 30 lb. per ft. for the reheat coils. Figures for Philo agree closely with these as shown by the tables.

Although operating difficulties in connection with reheating are not of importance, other complications of design and first cost leave the matter open to question and it appears doubtful if reheating is justified except under the most unusual conditions of a base load plant. Whether or not the live steam reheater will justify a wider application of the reheat cycle remains to be seen.

Get wise to the causes of accidents before one of the causes gets you, advises H. G. Wiberg of the National Safety Council.

Higher Superheats Demand Many Changes

INCREASED SUPERHEATS AND CHANGED BOILER PRACTICE MAKE NECESSARY THE APPLICATION OF NEW TYPES AND OTHER CHANGES TO GIVE THE DESIRED RESULT

UNLIKE PRESSURES which are determined solely by economic reasons, the total steam temperature is at present limited to a value of between 750 and 800 deg. by the metals now in use. There has been a

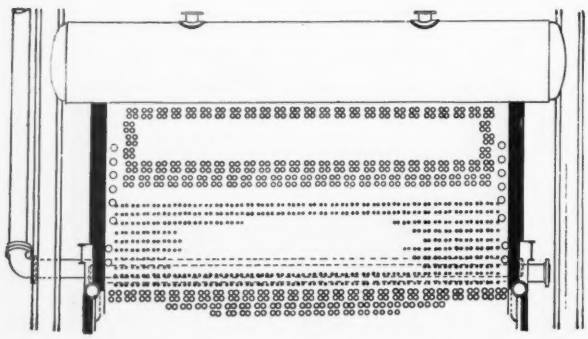


FIG. 1. LATE DESIGN FOR PULVERIZED COAL FURNACE TO GIVE HIGH SUPERHEAT AND EVEN DISTRIBUTION OF GAS ACROSS BOILER

decided increase of from 625 to a maximum of 750 deg. with at least more than a passing interest in the use of 800 deg., which both superheater and turbine manufacturers state is perfectly safe. Fragmentary reports from Europe indicate that attempts to go as high as 1000 deg. are under way. It is doubtful if values much in excess of 750 will be attempted on a commercial

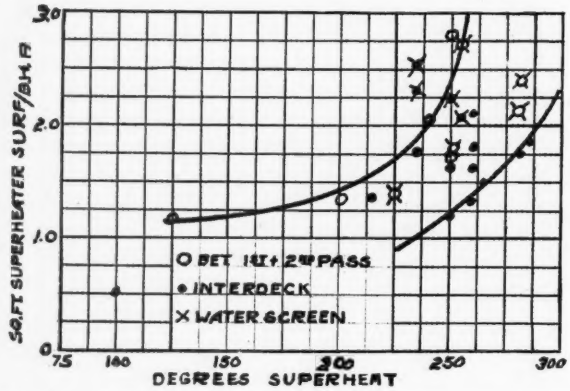


FIG. 2. VARIATION OF SUPERHEATER SURFACES SHOWS INFLUENCE OF HIGH RATINGS AND WATER SCREENS

scale in this country, however, until after some radical metal or alloy development has been announced and proved satisfactory in service.

Under a total temperature of 750 deg. the maximum superheat will vary from about 180 deg. at 1200 lb. to about 300 deg. at 400 lb. pressure. In actual practice stations of the type that formerly used 200 deg. are now going as high as 280 deg., the higher pressure station being of course limited to a maximum of about 250 or slightly over.

This increase in superheat, together with the increase in the use of water walls and screens has had an important bearing on the design and location of the superheating elements. Three types are now in common use. The convection type represented in the majority of stations, the radiant type as used in the water screen boiler of the Fordson plant and a combination of the two as used at Riverside.

RADIANT AND CONVECTION TYPES USED IN SERIES

Due to the different characteristics of the two types, a combination of the two in series can be proportioned so as to give an almost constant superheat over wide range of boiler loads. A comparatively small radiant surface is required to accomplish this. At Riverside a radiant surface of 89 sq. ft. is used with 2925 sq. ft. of convection coils to give practically a constant superheat of 250 deg. from 100 to 300 per cent of rating.

Additions and redesigns of old plants to give higher

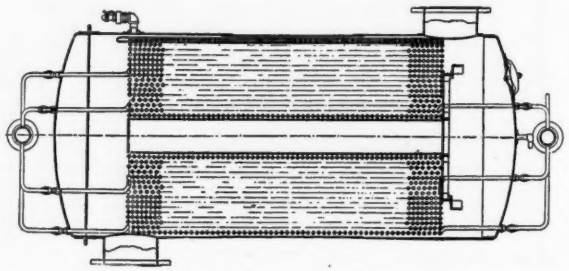


FIG. 3. TYPE OF LIVE STEAM RESUPERHEATER DESIGNED TO TAKE THE PLACE OF REHEAT BOILERS

ratings have found the radiant type of particular advantage. It is often extremely difficult, if not impossible to do anything about raising the superheat on a unit when the location and size are already determined. At the Fordson plant the boiler ratings were practically doubled and the additional superheat requirements successfully met by the radiant superheater installed in connection with the water screen boiler, which is entirely separate from the main boiler.

CONVECTION SUPERHEATER ELEMENTS BEING PLACED CLOSER TO FIRE

There has been a decided tendency to lower convection superheaters and place the elements nearer to the fire. Horizontal boilers are ordinarily built in two decks, leaving sufficient space between the two to install the superheater elements. Either the sixth and seventh or seventh and eighth rows are generally selected for this division, although there is a tendency to go even lower and the last installation reported has the superheater between the fourth and fifth rows. The arrangement is shown in Fig. 1, the four rows being reduced from four to three and finally to two at the edge of the boiler.

Gas velocities through the boiler are equalized and a uniform temperature maintained over all the superheater elements. Two useful purposes are served by changing the location. The superheat is increased and at the same time a much more constant superheat is obtained at vari-

ous loads. A large part of the boiler load is carried by the first rows of tubes and it is reasonable to expect that the superheater elements placed nearer the fire will be more nearly subject to the same variation in heat absorption as the boiler itself. Some difficulty, due to slagging and cleaning with tubes placed so low, has been reported but is not of a serious nature.

Water Screened Radiant Superheaters Important Development

Screening radiant superheaters behind water screens has been a big step toward remedying some of the difficulties encountered in the first installations. Forged steel elements have, in general, been found most satisfactory and cleaning difficulties, although more serious than with the convection type, have caused no great concern.

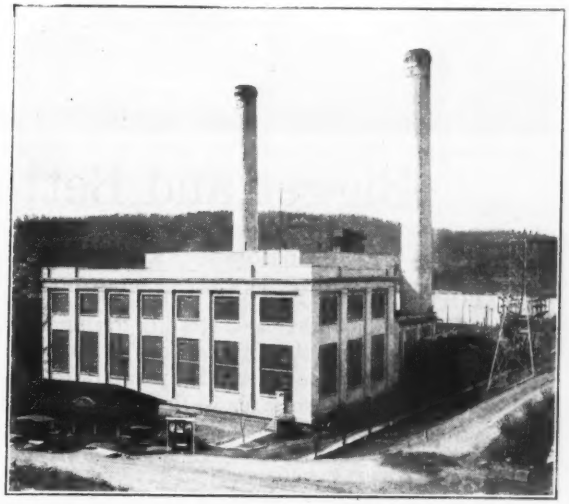
SUPERHEATERS

PLANT	TYPE	NO. OF BLRS	HEATING SURFACE PER BOILER		ELEMENTS		LOCATION	TEMPERATURE		
			SQ.FT.	% B.H.S.	DIA.	B.W.G.		SURR'T	TOTAL	RATING
COLUMBIA	CONV.	5 1	2,760 3184	18.25 21.05			8+9 ROW	260	750	
CRAWFORD	C	12	2,700	16.25			8+9 "	260	750	
PHILO	C	6	2,485	17.70			8+9 "	235	725	
TRENTON CHANNEL	C	8	6070	20.85			IN 1ST PASS	255	707	
RICHMOND	C	12	2822	18.00			1+2 PASS	251	707	
KEARNY	C	12	4130	17.50			6+7 ROW	281	720	
AVON	C	4	6,550	21.4			1+2 PASS	280	725	
SOMERSET	C	3	4060	27.2			1+2 "	258	700	200
NARRAGANSETT	C	2 2	4316 4316	23 25.3			6+7 ROW	233	675	200
EDGAR	C	3	2938	14.90			6+7 "	265	707	200
LONG BEACH	C	11 4	7813 AV. 3574	52.10 24.0	1 5/8"	9	1+2 PASS	281	725	300
SEAL BEACH	C	3	3331	13.11			6+7 ROW	257	700	
SUSQUEHANNA	C	6	2130	14.42	1 3/4	9	1+2 PASS	225	660	200
SAHOKIA	C	16	4070	22.60			6+7 ROW	250	686	
RIVERSIDE	C RAD.	4	2925 89	28.05 .85			1+2 PASS	250	705	
WAUKEGAN	C	6	2286	16.30			8+9 ROW	250	700	
VALMONT	C	4	6288	57.80			BET. INCL.+ VERT TUBES	200	640	
HALES BAR	C	3 2	2,000	18.60			8+9 ROW	285	725	
BIG SIOUX	C	4	2278	20.50			1+2 PASS	240	677	200
NEOSHO	C	3	2008	16.75			1+2 "	250	685	200
DRESSER	C	8	2424	14.05			6+7 ROW	215	650	
EDGEWATER	C	3	7342	50.50			BET. INCL.+ VERT. TUBES	200	622	200
BARBADOES	C	3	2300	13.70	1½	9	8+9 ROWS	200	625	
PINE GROVE	C	6	1057	13.30			1+2 PASS	200	622	
IRON MT.	C	4	800	5.00	1 3/4	10	IN 1ST PASS	100	505	200
FORDSON	C (R)	6 2	3144 (348) (348)	11.88 1.34 3.36	1 5/8 1 3/4	9 6	IN 1ST " " BEHIND FIN TUB.	250	636	315
BROTHERHOOD OF L.E. BLDG.	C	4	473	11.50	1½	9	1+2 PASS	125	525	
BETTENDORF	C	6	138	4.48	1½	9	ENTRANCE	85	450	100
BAYONNE	C	8					1+2 PASS	150	530	

Conditions of superheat, location and design have changed so rapidly that no definite value can be set for the proportioning of the surface in relation to the boiler heating surface. Furnace design, particularly water screen surfaces, and location are most important. Eighteen per cent seems to be a fair average value for all the plants considered, regardless of superheat or location. When plotted with superheat surface and per cent of the boiler heating surface against superheat in degrees as in Fig. 2, the plants where the elements are located between the first and second pass show considerable agreement. Interdeck locations show no such agreement though in general the surfaces run lower than those between passes. Plants with water screens all come well above the lower curve, showing the varying effect of water screens on the elements installed in different locations.

Live Steam Reheater Simplifies Reheat Problems

Reheating between turbine stages so as to eliminate moisture and obtain dry steam throughout the entire expansion in the turbine has been practiced for some time by using special boilers for this purpose. This might be better termed "resuperheating" and the past year has brought out an important development in this



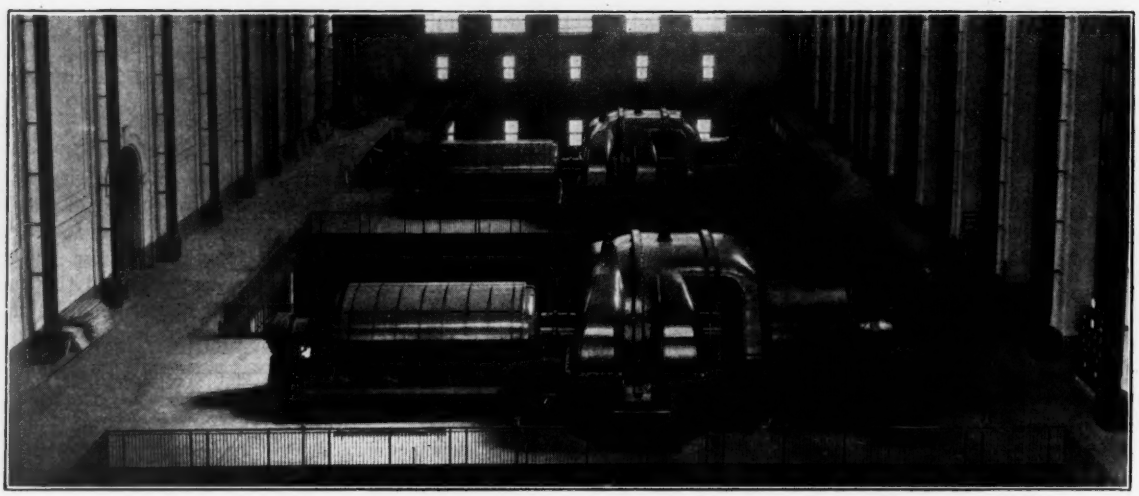
THE HALES BAR STATION

line. The heater shown in Fig. 3, designed to use live steam, is to be installed in connection with two new units, one of 104,000 kw., the other 208,000 kw.

Live steam to the extent of about 5 per cent of the weight of the low-pressure steam reheated is required for each 100 deg. of superheat and the temperature can be raised to between 30 and 50 deg. above the saturation temperature of the live steam. This is considerably lower than can be obtained in a boiler but has the advantage of eliminating long, low-pressure steam lines, complicated turbine and boiler control, as well as the pressure drop through these lines. The heater is placed in the turbine room at one end of the turbine, making a very simple arrangement and reducing the pressure drop to a negligible value.

Many plant superintendents use common salt to prevent freezing of fire fighting apparatus. This is satisfactory, if the containers are wood and if the temperature never goes below zero. Salt solution will always rust metal, however, and, not infrequently, has a tendency to creep or crystallize on the container. Calcium chloride, it is felt, gives a safer and more satisfactory solution.

Where many steam traps are used it pays to have them inspected frequently and regularly to detect leakage or improper action.



Bigger and Better Turbines Ahead

DEVELOPMENTS SHOW TREND TOWARD HIGHER PRESSURES AND TEMPERATURES, REHEAT AND EXTRACTION. BY A. G. CHRISTIE*

DEVELOPMENT OF STEAM TURBINES in the United States has progressed steadily during 1926. Naturally the greatest publicity has been given to increases in size and in pressures and temperatures. Some notable advances have been made in these regards. At the same time improvements in both design and performance have been made in the smaller sized units suitable for industrial plants, and particularly in non-condensing and extraction turbines, which may be installed where commercial use will be made of the steam that leaves the turbine. Generators have also received further study and development. Details of construction demand close attention, and new blading materials are finding wider application. In general, it can be stated that the turbines of 1926 are better built and more reliable than earlier units and therefore should have higher availability factors.

PRESSURES AND TEMPERATURES

Higher steam pressures were adopted for several large public utility central stations a few years ago. The number of stations using steam pressures of 500 to 600 lb. gage is steadily increasing. Steam temperatures in the neighborhood of 700 degrees F. have been employed for several years, and these have only been exceeded slightly in a few cases with the turbines furnished during 1926. The maximum temperature now proposed in this country is 750 degrees F. It was believed for some time that available metals would not stand temperatures in excess of this amount on account of the decrease in tensile strength. This is now recognized as a mistaken idea in view of the fact that the fatigue limit, rather than the tensile strength, governs the working life of metals, and that the former decreases only slightly with increased temperatures up to 1000 degrees F.

A more important consideration is the phenomenon of "creep" or permanent stretching of the metal under relatively low loading at high temperatures. This characteristic of various metals is still little known, and much research is being conducted to study the nature of "creep."

A real problem with increased temperature is the probability of dissociation of the steam by hot superheater tubes and the disastrous effects of such free oxygen as may result from dissociation, on the superheater tubes, the main steam piping, and the turbine blades. This problem of dissociation is now receiving careful study both here and abroad, and data will soon be available on its possible effects. If this difficulty is not serious, steam temperatures will probably be increased to 850 degrees F. or higher in the immediate future.

When high pressures are used, the steam may be reheated at some intermediate stage in its expansion either by carrying the steam back to a secondary superheater in the boiler, producing high superheat, or, by means of live steam reheaters, giving a moderate superheat. The object of reheating is to reduce wetness in the steam passing through the last stages of the turbine. Reheating is a complicated and expensive procedure. If the initial superheat could be raised to 850 degrees F., reheating would not be so necessary, and a cheaper and simpler plant would result. In fact this would accelerate the adoption of high pressures in industrial plants as well as in central stations. Such a trend may be expected within a few years if this high temperature can be safely used.

Two stations employ boiler pressures of 1200 lb. or higher. The high pressure turbine at Edgar Station, Boston is reported to have operated satisfactorily during the past year. The turbine at Lakeside Station, Milwaukee has been under steam, and will probably be in regular service when this article appears.

The desirability of high steam pressures in industrial plants is now better recognized, particularly where steam is required for process work or central heating. Cheap electrical power can be generated when high pressures are used.

While there appears to be a definite trend towards higher pressures, a note of warning should be sounded.

*Professor of Mechanical Engineering, The Johns Hopkins University.

Most of the high pressure installations to date have been planned to operate at unusually high load factors. These high load factors can not be provided in many plants, and careful studies at low load factors frequently indicate that moderate pressures permit the production of the cheapest power. This ultimate cost of power should govern the selection of the steam pressure.

Sizes and Speeds

The largest turbine announced to date is the 208,000-kw. General Electric unit now under design for the State Line Generating Station in Indiana. This is a 3 unit set at 1800 r.p.m. with one high pressure and two low pressure turbines. It will operate with 600 lb. gage, 750 degrees F. at the throttle, and with steam reheated by live steam between cylinders to 500 degrees F. Other notable units from the point of exceptional size, are the 160,000-kw. compound turbine under construction by American Brown Boveri Company for Hell Gate Station, New York; the 90,000-kw. sets for Crawford Avenue, Chicago and for Southern California Edison, Los Angeles; the 80,000-kw. unit for Hudson Avenue, Brooklyn; the 60,000-kw. single-cylinder, 25-cycle unit for Buffalo General Electric Company; the 50,000-kw. single cylinder, 1800 r.p.m. unit for Cahokia Station, St. Louis, and the 50,000-kw. Allis-Chalmers unit for Waukegan, Illinois. All of these represent substantial advances over previous construction. The installation of such large units has been warranted not so much on the basis of increased efficiency, (which gain over earlier units will be of a relatively small order), as by decreased unit plant costs, and by the suitability of such large units to carry the base-load portions of the rapidly growing loads of these public utility systems.

Improvements in economy in smaller units have been secured by the use of reduction gearing, by improvements in detail design, and by building turbines for higher r.p.m. In Europe, 20,000-kw. turbines at 3000 r.p.m. are in service abroad. The probable limit of size at 3600 r.p.m. is about 15,000 kw. These units will show high economy.

Special Purpose Turbines

Provision has been made on all recent large turbines for the extraction of steam at various stages to heat the feed water on the regenerative cycle. Turbines have been bled at as many as four points for this purpose. Such procedure results in substantial reductions in the heat consumption of the plant as a whole. This desirable construction has only recently been applied to small turbines such as are used in the average industrial plant. The first cost of the equipment is increased by the added pipes and heaters, and the layout becomes more complicated. On the other hand, operation is very simple, and the improved station economy soon repays the added cost. The regenerative cycle should be more widely adopted in industrial plants.

Many regenerative turbines are sold with guarantees based on non-bleeding conditions, and are therefore designed to meet those guarantees. The best interests of the purchaser would be met if these units were designed and guaranteed for bleeding operation, and this plan is recommended in preparing specifications for purchasing such turbines. They will present some difficulty in testing, but this will be offset by a small improvement in station economy.

Several industrial plants requiring process steam have installed high pressure boilers and either extraction or non-condensing turbines to utilize the heat head down to process pressure, for developing the power needed in the plant. Generally this plan provides cheap electricity. For instance, Parson's turbines of 1500 kw. each, geared to direct current generators, are being supplied to a Canadian industrial plant. These receive steam at 300 lb. gage, 700 degrees F. and exhaust at 5 lb. gage, and have a bleeder at about 40 lb. gage. Without bleeders the overall efficiency ratio of these units is guaranteed at 70 per cent, based on electrical output, which is good for such units.

High pressure turbines are also being adopted by several plants supplying central heating systems. Undoubtedly there are many places where these high pressure non-condensing turbines can be adapted to advantage with heating systems. Special turbines have been developed for these purposes and are understood to be operating satisfactorily.

The economy of small steam turbines has been appreciably increased during the past few years. This will encourage an extended use of steam turbines for auxiliary drive in place of electric motors, particularly when consideration is given to the reliability and availability of the steam driven units, and also where speed variation requires complicated and expensive motor control systems.

A modified mercury boiler and turbine equipment has recently been installed and operated at the Hartford Electric Company. The performance of this unit is said to be sufficiently satisfactory to warrant the further development of this type on a commercial basis.

The use of diphenyl oxide in place of mercury has been suggested, and research is now being conducted to determine its possibilities.

Generators

Turbo-generators recently installed in central stations are nearly all designed for closed-circuit air circulation with tubular air coolers of the fin type. This not only lessens the fire risk, but prolongs the life of the insulation as no dust or dirt is admitted to plug up the air slots. Furthermore, the distribution of the ventilating air over the generator winding, and the heat-dissipating capacity of the revolving fields, have been materially improved. These advantages are now being applied to the smaller units, and will better the performance, increase the efficiency, and lengthen the life of turbo-generators, particularly when they must operate in dirty atmospheres.

The use of hydrogen as a cooling medium in turbo-generators has been studied and tried experimentally. So far it has not been adopted in a commercial unit. It appears to have interesting possibilities.

Various schemes for supplying power for steam turbine auxiliaries have been tried. During the past year there seems to be a distinct trend, when motor drives are used, towards the use of an auxiliary generator directly connected to the main turbine, to supply this auxiliary power. This arrangement provides energy to the auxiliaries at the lowest possible steam consumption, and has many desirable features.

Turbine users will view with gratification the studies

of details now being conducted by manufacturers. The substantial improvements that result from such studies are reflected in the better turbines now being built.

The development of methods for testing vibration in discs and blades in large turbines has largely eliminated the probability of difficulty from these sources in recent units. As a result of this, attention has now been directed to other causes of vibration particularly to the resonant vibration tendencies of the steel foundation structures at or near the running speed of the turbines. It is becoming apparent that engineers must give careful study to foundations, and pipe connections in order to eliminate all troublesome vibrations.

Studies of blading materials have continued and new materials such as stainless and other alloy steels, are now used, while the applicability and special uses of the older materials such as copper-nickel alloys, monel, and nickel steels, are better understood. Blade designs have been greatly improved as a result of a better understanding of the causes of fatigue failures, and of the serious effects of internal stresses that may be set up in the blading material at some stage of the construction of the turbine.

Engineers now appreciate the need of oxygen-free steam if corrosion of the low pressure blading would be prevented. Oxygen should be removed from the feed water either by special provisions in the condenser, or by a separate deaerating equipment. Greater attention should be given to the design of pump glands to prevent leakage of oxygen into the feed system.

One large company is spending money on the investigation of the losses in nozzles and blade passages. This is most encouraging, for the possibilities of further improvements in economy of small and medium sized turbines lie largely in the reduction of losses in the nozzles, blading, discs, and glands, and the application of pure stream-line flow to the design of all blades and steam passages.

Real improvements have been made in the methods of forging, heat treating, and inspecting spindles and discs for steam turbines. Failures of these parts from defects are becoming rare.

It will be evident that the reliability of the turbine of 1926 must be greater than that of its predecessors in view of these developments. Further progress is tending towards the production of units of still greater reliability and availability, so that we may expect still better turbines in 1927.

Analysis of Present-Day Turbine Installations

Comments on Pressures and Temperatures Employed, Use of Reheat, Turbine Arrangement and Extraction for Feed Water Heating

KEEPING IN MIND the general course of steam turbine development during the past two years pointed out in the foregoing article, it may be of interest to discuss in some detail the various plants shown in the accompanying table. They illustrate well the trends toward higher pressures and temperatures, the use of the extraction of steam from various parts of the turbine for feed water heating, the use of reheat with some of the larger units and other points that have been mentioned.

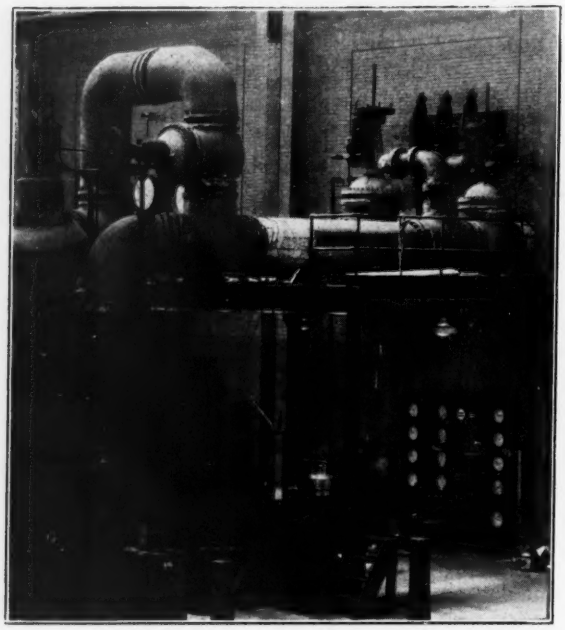


FIG. 1. SINGLE CYLINDER, 40,000-KW. TURBINES AS USED AT PHILO, SHOWING ARRANGEMENT OF REHEAT PIPING

Of the plants shown in the accompanying table, the first three illustrate present practice in using high pressures and temperatures in steam power plants. At Columbia plant the turbines are designed for a pressure of 550 to 600 lb. gage, and a temperature of 750 deg. F. The turbines at Crawford and Philo are designed for throttle pressures of 550 lb. with a total steam temperature of 725 deg. F. The next highest pressure is that at Riverside, 400 lb. with a total temperature of 700 deg. at the throttle. With this exception and the exception of the small turbine at Edgar Station, employing 1200 lb. pressure, it will be noticed that the remainder of the plants after Philo use pressures from 375 lb. down to 140. For industrial plants such as Iron Mountain, Fordson, B. of L. E., it will be noted that the pressure is not over 250 lb., although the temperature is kept well up to secure the advantages of the superheat. It will be noted also that in many cases where the steam pressure is 350 or 325 lb. the total steam temperature is kept up to 675 deg. and even 700. This is the case with the turbines at Kearny, Edgar, Seal Beach, Susquehanna and several others that will be noted.

Edgar Uses a 1200-Lb. Turbine

At Edgar station the operation of a turbine at a throttle pressure of 1200 lb. per sq. in. gage is typical of the practice employed in the only two plants in this country using this pressure, one of these being Edgar, the other being Lakeside plant at Milwaukee. The turbine at Edgar station takes steam at the throttle at 1200 lb. and a total temperature of 700 deg. exhausting

it at 360 lb. gage, at which pressure it is reheated, as will be noted later.

Of the plants that have installed turbines equipped for reheating, the four plants noted on the accompanying table are typical of present practice. The first of these is Columbia station using 26-stage turbines with 14 stages in the high pressure cylinder and 12 in the low pressure. After the steam has passed the 14th stage, the entire volume of steam is conducted to the reheat boiler at a pressure of about 135 lb. absolute, and is there reheated to a total temperature of 725 deg. and then returned to the 15th stage of the turbine which is the first stage of the low-pressure cylinder. At the Crawford Avenue station reheat is employed on the first three units installed in the station, but it is understood that with the fourth unit, rated at 75,000-kw. capacity, no reheat will be used. On the No. 1 unit the total volume of steam is extracted from the turbine at 115 lb. absolute, and reheated to 700 deg. total temperature. On the No. 2 turbine it is reheated at 120 lb. pressure and on the No. 3 unit at 132 lb. pressure. These pressures are the ones for which the turbine was designed, but it has been found in practice that there has been some variation from them. At Philo the steam is taken from the turbine after the seventh stage at a pressure of 150 lb. absolute and reheated to 725 deg.

STEAM TURBINES

PLANT	NO OF UNITS	TYPE	RATED CAPACITY EACH	NO OF STAGES H.P.	NO OF STAGES I.P.	NO OF STAGES L.P.	TOTAL NO OF STAGES	THROTTLE PRESS LB.GA.	THROTTLE TEMP.	EXH. PRESS ABS. IN.HG.	REHEAT PRESS. LB.ABS	REHEAT TEMP AFTER	SPEED	STEAM EXTRACTION STAGES	STEAM EXTRACTION PRESSURE LB. ABS.	STEAM EXTRACTION TEMP.	STEAM EXTRACTION PURPOSE
COLUMBIA	2	TANDEM COMPOUND	45,000 KW	14		12	26	550 600	750	1	135	725	1800	18 GLAND 22 24	40.0 14.0 4.7 2.85		F.W.HEAT
CRAWFORD	NO. 1 " 2 " 3 " 4	TRIPLE EXP. CROSS COMP. TRIPLE EXP. CROSS COMP.	50,000 K.W. 60,000 K.W. 50,000 K.W. 75,000 K.W.	36 10 15 15	23 15 15	5 14 9 † 9 †	64 24 39	550	725	¾ TO 1 IN.	115 120 132	700	720 * 1200 1800		3.5 13.0 50.0 150.0		F.W. HEAT
PHILO	2	SINGLE CYLIN. IMPULSE	40,000 K.W. 0.95 P.F.				19	550	725		7TH ST. 150	725			6 15	170 220	F.W. HEAT
TRENTON CHANNEL	4	HORIZONTAL IMPULSE	62,500 KV.A. 50,000 K.W.				21	375	700		NONE		1200	14 17 19	32 9.7 3.1	255 142 143	F.W. HEAT
RICHMOND	2	IMPULSE	50,000 K.W.	TANDEM COMP.			20	375	675				1800	10 12 15 18	129.6 74.3 28.3 5.6		EVAP. F.W. & EVAP. F.W. & DEAERATR F.W. HEAT
KEARNY	5		3-37,200 KV.A. 2-43,750 KV.A.					325	700		NONE		1800		145 55 8 4		F.W.HEAT
AVON	2	SINGLE CYL. IMPULSE	35,000 KW. 0.8 P.F.				17	375	700				1800	14 TH	6.65		F.W. HEAT
SOMERSET	1	37,500 KV.A.						350	700	1	NONE		1800	15 12 10 7	3 17 38 110		F.W. HEAT
NARRAGANSETT	1	SINGLE CYL. IMPULSE	43,750 KV.A.				17	350	635					8 12 14			F.W.HEAT MAKE UP
EDGAR	2 1	SINGLE CYL. SINGLE FLOW IMPULSE	32,000 K.W. 3150 KV.A.				17 20	350 1200	700 700	360 LB GA.	1200 # STEAM EXPANDED TO 360 & REHEATED TO 700 DEG.		1800 3600	L.P. GLAND H.P. NONE	3.89 14.7 26.0		F.W. HEAT
LONG BEACH	3	SINGLE CYLINDER	2-37,800 KW. 1-52,800 KW.				20	365	725	1.5	NONE		1500	11 15 18	7+8 #9 62.7-85 17.0-23 3.4-4.3		F.W. HEAT
SEAL BEACH	1	PARALLEL FLOW IMP. & REACT.	30,000 K.W.	2 ROWS IMP. 14 " REACT. 6 " BAUMANN			27	350	700		NONE		1800		WATER LEAVES HEATER AT 152, 212,	278+362	F.W. HEAT
SUSQUEHANNA	2	IMPULSE	1-30,000 KW. 1-35,000 KW				17	325	650		NONE		1800	GLAND-10 13 15	50.3 12.4 3.32		F.W.H & EVAP.
CAHOKIA	4	2 SINGLE CYL. 2 SEMI DBL. FLOW SINGLE CYL.	35,000 KV.A.				17	300	600	0.7-2"	NONE		1800	1 TO 3			F.W.HEAT
RIVERSIDE	1	BLEEDER COND. SINGLE CYL.	25,000 KV.A.					400	700	1	NONE		1800		149 10-15 2-5	386	F.W.HEAT EVAP.+3RD HTR. 4TH.STG. HTR.
WAUKEGAN	2	REACTION 1 CYL.	1-25,000 KW. 2-35,000					350	675	1	NONE		1800	UNIT NO 1 " " 2	38LB-18 75; 25.4		F.W.H.
VALMONT	2		1-20,000 KW. 1-25,000 KW.					350	625		NONE		1800		3 14 53		F.W.H.
HALES BAR	2	SINGLE CYL.	25,000 KV.A.				14	386	725	1	NONE		1800	3 7	135 20	210	EVAP. MAKE UP
BIG SIOUX	2	SINGLE CYL.	11,250 KW. 0.9 P.F.				9	325	675	1.5	NONE			4 7	19.0 3.75		F.W.
NEOSHO	1	SINGLE CYL.	15,000 KW.					350	750		NONE		1800	2 BLEED	POINTS		F.W. H.
DRESSER	2	SINGLE FLOW IMP. & REACT.						300	650	1	NONE		1800		5.6 16.4		F.W.H.
EDGEWATER	1		25,000 KV.A.					300	625	1	NONE		1800	NONE			
BARBADOES	2	1 SEMI DBL FLOW 1 SINGLE FLOW	25000 KV.A.				28	250	625	1.6	NONE		1800	1ST UNIT 2ª UNIT	18.5 16.93-9.20		F.W.H.
PINE GROVE	2	SINGLE CYL.	15,625 KV.A.					300	625		NONE		1800	NONE			
IRON MT.	7	SINGLE CYLINDER	1-5000 K.W. 6-750 KW.	2 STAGES			2	250	510	20 LB.				2 BLEED -NOT	POINTS- USED		
FORDSON	8 ULT.	IMPULSE	62,500 HP 30,000 KW.	1-2 ROW VELOC. 14 SINGLE " LAST 4 STG. DBL. FLOW			15	230	655	0.5	NONE		1200	NONE			
BROTHERHOOD OF L.E. BLDG.	4	HIGH EFFICIENCY RECIP. ENGINES	2-750 KW. 2-250 KW.	1125 HP 400 HP				235	525	17LB.	NONE		150 + 200	NONE			
BETTENDORF	2	REACTION	2500 KW. EA.					140	400	2"	NONE		3600	NONE			
BAYONNE		DATA	NOT	AVAILABLE													

* NO. 1 - 1800 RPM. H.P. † I.P. 720 L.P.
NO. 2 - 1800 " " 1200 L.P.
NO. 3 - 1800 " BOTH CYL.
NO. 4 - 1800 " H.P. 1200 L.P.

† DOUBLE FLOW

The 1200-lb. turbine at Edgar station as noted above, exhausts at 360 lb., the entire exhaust from the turbine being reheated in the reheat boiler to 700 deg. total temperature and returned to the main steam header of the rest of the station at about 350 lb. pressure.

Turbines for Industrial Plants

Turbines at the Iron Mountain plant are typical of many recent industrial installations. The exhaust from these turbines is used at a pressure of about 5 lb. gage or 20 lb. absolute in a large battery of dry kilns and also in the heating system of a large factory. Other industrial turbine installations are now being made using various initial pressures, in one case as high as 800 lb. per sq. in., and expanding the steam in the turbine down to a pressure necessary for some part of the process work, possibly 150 lb. or 200 lb.

In the matter of sizes, Professor Christie has already called attention to some of the large turbines now under

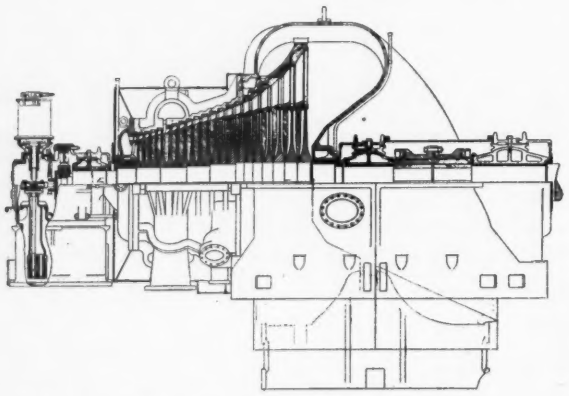


FIG. 2. CROSS SECTION OF A 45,000-KW., 21-STAGE STEAM TURBINE

construction or installation at various important central stations. Of the units tabulated here, the largest one in actual operation is the 75,000-kw. unit at Crawford Avenue. Other large units of particular interest are the 50,000-kw. and 60,000-kw. units at Crawford, the 50,000-kw. units at Trenton Channel, the 45,000-kw. machines at Columbia, and the latest unit at Long Beach, which is rated at 52,800 kw.

Speeds of Various Units

Most of the units tabulated here, as will be seen, operate at a speed of 1800 r.p.m. There are some exceptions to this, however. It will be noted that the units at Trenton Channel plant operate at 1200 r.p.m., while the units at Long Beach plant operate at 1500 r.p.m., the latter speed made necessary by the 50-cycle generators installed there. The turbines at the Fordson plant were designed and built by the engineers of the Ford Motor Co., and operate at 1200 r.p.m., while the small reaction units at Bettendorf plant operate at 3600 r.p.m.

Speeds of the various turbines installed at Crawford Avenue vary according to the type of turbine and the design. In the No. 1 machine, the low-pressure and intermediate-pressure cylinders are set with their shafts on the same center line, although they are independent machines, each driving separate generators and operating at different speeds. The high-pressure unit is set beside the two. The low-pressure turbine operates at 720 r.p.m., driving a 6000-kw. generator, while the intermediate pressure turbine operates at 1800 r.p.m. driving a 29,000-kw. generator. The high-pressure unit also operates at 1800 r.p.m. In the No. 2 machine, which is a two-cylinder machine, cross-compounded, the high-pressure cylinder operates at 1800 r.p.m. and the low pressure at 1200. The No. 3 machine has the high-pressure and intermediate-pressure cylinder in tandem, the turbine wheels being on the same shaft. The low-pressure cylinder is set beside these two. Both rotors operate at 1800 r.p.m. The arrangement of No. 4 unit is similar to that of No. 2, namely a high-pressure and low-pressure cylinder, the high-pressure operating at 1800 and the low at 1200 r.p.m.

With the exception of the turbines at Crawford Avenue, and the turbines at Columbia and Richmond, many of the plants tabulated here are using single-cylinder machines. The turbines at Columbia are of the impulse type with a high and low-pressure cylinder, tandem compounded. The same arrangement is used on the turbines at Richmond. At Seal Beach a parallel flow combination impulse and reaction turbine is installed rated at 30,000 kw. This contains two rows of impulse blades, nineteen rows of reaction blades, and six rows of Baumann blades. The Ford turbines, as installed at Iron Mountain and Fordson, present some points of interest. The 5000-kw. and 750-kw. turbines installed at Iron Mountain are single-cylinder machines with two stages each. At the Fordson plant the turbines are rated at 62,500 hp., the generator rating being given as 30,000 kw. These turbines have a total of 15 stages each. They are of the impulse type with one two-row velocity stage followed by fourteen single velocity stages, the last four stages of these being double flow. Typical of the single-cylinder type of unit installed in some of the larger sizes are the 40,000-kw. turbines at Philo, the 50,000-kw. units at Trenton Channel, the units at Kearney rated at 43,750 kv-a. and 39,200 kv-a., the Avon units of 35,000 kw. and so on.

Number of Stages

With various sizes of turbines, the number of stages will vary of course, and it will also vary according to the type. The 45,000-kw. tandem compound turbines at Columbia have a total of 26 stages, 14 in the high-pressure and 12 in the low-pressure cylinder. The No. 1 unit at Crawford is a 60,000-kw. reaction machine with a total of 64 stages, 36 of these being in the high-pressure cylinder, 23 in the intermediate-pressure and 5 in the low. The No. 2 unit at Crawford has 24 stages, 10 in the high-pressure and 14 in the low-pressure cylinder, while the No. 3 unit has a total of 39 stages, 15 of these high-pressure, 15 intermediate, and the remaining 9 low-pressure. The 9 low-pressure stages are of the double-flow type. The single-cylinder machines in sizes from 30,000 to 50,000 kw. usually have between 17 and 21 stages.

It has been pointed out elsewhere that there seems to be a definite trend toward the use of steam extracted from various stages of the turbine for heating the feed water, this arrangement being used in conjunction with air preheaters or economizers or both on the boilers, depending upon how the heat balance of

each particular station is worked out. It will be noted that practically all of the turbines mentioned in the accompanying tabulation are equipped for extraction of steam for feed water heating. One important exception to this is the turbines at Fordson, which are not provided with bleed points. There is, of course, no uniformity about the points at which various types and sizes of turbines are bled for heating feed water, since these points must be determined when the heat balance of the whole station is worked out. Many of these turbines extract steam at three points from the turbine, and several from four points.

In most cases the lowest pressure at which steam is extracted from the turbines about 3 or 4 lb. absolute. On the other end, however, there is no such uniformity. The highest stage of extraction on the Columbia turbines is 40 lb., while the highest point on the turbines at Crawford is somewhere near 150 lb. It may be mentioned in passing that the figures given for the extraction pressures on the Crawford turbines are average and approximate for all the units. These figures will vary of course, not only with the load on the unit, but with the different types of units. It should also be noted that the extraction pressures as tabulated for the various plants are those for which the turbines were originally designed, as far as information was available and some changes may have been made which would cause these pressures to vary from the ones originally designed for.

Two bleed points at 6 and 15 lb. absolute are used on the turbines at Philo, while four are used on the Richmond turbines. In the latter case steam from the 10th stage at 129.6 lb. absolute is taken to the evaporator, steam from the 12th stage at 79.3 lb. goes to feed water heaters and evaporators. Steam from the 15th stage at 28.3 lb. goes to feed water heaters and deaerator, and from the 18th stage at 5.6 lb. to a feed water heater. The 35,000-kw. turbines at Avon plant are equipped with only one bleed point at the 14th stage at a pressure of 6.65 lb. absolute, used for feed water heating, and it is doubtful if any more stages will be bled from these turbines for this purpose. Each of the turbines at Hales Bar is equipped for bleeding from two stages, the 3rd and 7th, from the 3rd at a pressure of 135 lb. absolute and from the 7th at a pressure of 20 lb. absolute. These are so arranged, however, that only one bleed point can be used at a time on each turbine, although different pressures may be used on the separate turbines. At Barbadoes Island one unit is equipped for bleeding at only one point, at 18.5 lb. pressure, while the second unit can be bled at 16.93 lb. and also at 4.20 lb. The 5000-kw. and 750-kw. units at Iron Mountain are provided with two bleed points, but these are not used.

Development in Steam Turbine Construction

Discussion of Types and of Changes Made During Past Two Years in Blading, Staging and Bleeding, and Consideration of Changed Steam Conditions

CAPACITY trend in steam turbines has continued on the increase during the past 2 yr. This trend has presented problems of increasingly heavier construction and operation, which have engaged the best minds in the engineering and metallurgical professions to the end that much higher pressures, temperatures and speeds have resulted.

Types

Comparatively few steam turbines are now being installed that operate entirely on either the reaction or the impulse principle. Those manufacturers who originally constructed their turbines on the reaction principle are now, for the most part, adding at least a few sets of impulse blades. In the accompanying table this latter type is indicated as "Combination."

While compound turbines are likely to be used for the higher pressures and larger capacities, the outstanding tendency on the part of an increasing number of operating companies appears to be toward the use of larger and larger turbines of the single-cylinder design. This latter trend is best exemplified by the specification of the 60,000-kw., single-cylinder turbines for the new East River Station of the New York Edison Co.

Blading

No increase can be seen of the use of the double-flow system; the single-flow and parallel-flow types being at present most commonly installed. Besides the usual considerations of centrifugal stresses in blade design the equally important one of the elimination of possible nodal vibrations which may cause breakage at much below the normally allowable stress is now being given considerable attention.

Adoption of special blading at the low pressure end of the turbine has increased during the past 2 yr. The limiting size of a steam turbine is the area of the low-pressure blades or the annulus occupied by the last row of blades. A solution of this difficulty lies in the division of flow in the low-pressure side. Multiple exhaust blading of warped surface and tapering section type has been introduced to reduce the maximum stresses due to centrifugal action. This arrangement permits the attainment of large outputs at high speeds without the use of blades having excessive lengths or large diameter disks which involve high stresses.

Staging and Bleeding

Seventeen overall stages appear to be more generally adopted in main units now than stages of lesser or greater number although the range is great; sixty-four being used in one of the units in the Crawford plant while only nine are used in the Big Sioux plant.

Provision for stage bleeding is now almost universal in modern plants. A year ago only three plants in the United States were using four bleeding stages; this number has doubled in the past year.

A number of plants, although at present using a single or few bleed stages, have provided four bleed stages for possible future use.

Increase of steam temperatures has not kept pace with increased steam pressures. The tendency is to limit the steam temperature at the throttle to about 725 deg. F.

Little trouble has been experienced with steam pressures thus far used. There are now three large installations in this country employing 600 lb. pressure about to go into service. Two plants have been in successful operation with 1200 lb. pressure and pressures of 3200 lb. have been proposed.

Increase of temperature, however, has a much more definite effect. The difficulty lies not so much in the greater temperature as it does in the effect of large temperature change on the strength of parts. Unequal heating and cooling which takes place particularly when starting up and shutting down a turbine is aggravated by the unequal coefficient of expansion of the materials used. Fortunately, particularly in the case of large turbines, much higher economies from a theoretical standpoint are to be secured by increasing

PINE GROVE STATION

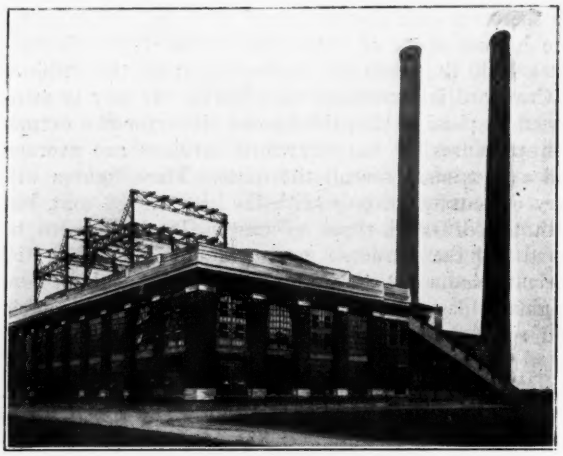
the pressure rather than the superheat. It should be realized, however, that higher pressures bring about much greater quantity of condensate. Likewise an increase in vacuum increases the total steam volume and steam velocity leaving the last wheel of the turbine. The increase in the kinetic energy loss in the steam going to the condenser results in a decreased Rankine cycle efficiency ratio. The greater the load carried by the turbine, the more marked this effect becomes.

Combining super-pressure turbines with lower pressure turbines by having the former exhaust into the latter at comparatively high pressure reduces the temperature range in any one turbine although exceedingly high overall temperature and pressure range is employed.

Low back pressures have been maintained to high points of vacuum through the use of efficient condensing apparatus. It must be apparent, however, that an increase in vacuum increases the total steam volume and the steam velocity leaving the last wheel of the turbine.

Reheating of steam at bleeding points is being resorted to with increasing favor. Single-stage reheating at about 550 lb. gage at the throttle is becoming common practice.

Reheating of steam and hence reduction or elimination of moisture appears to reduce blade erosion and increase the Rankine cycle efficiency for the lower stages. Rankine cycle efficiency ratios are higher in the high-pressure stages than for low-pressure stages where the steam is likely to be wet. Thus the overall efficiency



THE NEOSHO PLANT

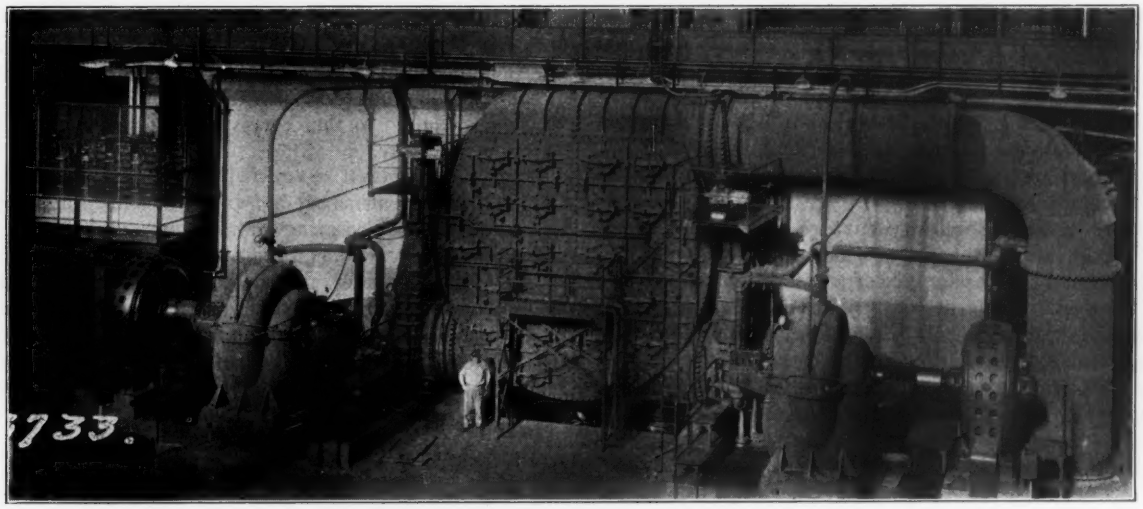
of a turbine operating on the regenerative cycle will be increased.

Extraction and reheating tend to flatten the economy curve of a turbine. Nearly equally good economy may be obtained under these conditions at ¼, ½, ¾ or full load.

Efficiency is increased by removing steam from the turbine shell at a point near the saturation temperature, resuperheating generally in a reheat boiler, and returning it to the steam path. By repeating this a number of times, a completely dry cycle may be maintained. The gain in reheating, however, is somewhat offset by the increased cost of apparatus.

WATER REQUIRED for cooling air compressors depends upon the type of machine and the temperature of the water. The following table gives the amount of water which would normally be required for each 100 cu. ft. of free air actually delivered by various machines.

Water Temperature	60	70	80	90
Jacket—Single-stage comp., 40 lb. pres.	0.5	0.6	0.7	0.9
Jacket—Single-stage comp., 100 lb. pres.	0.8	0.9	1.0	1.2
Jackets—2-stage comp., 80-100 lb. pres.	.85	1.0	1.2	1.4
Intercooler—2-stage comp., 80-100 lb. pres.	2.5	3.0	3.5	4.0
Jackets and Intercooler in Series—2-stage comp.	2.9	3.4	4.0	4.5



Condenser Practice Trends Well Defined

STEAM EXTRACTION AND INCREASED SIZE OF UNITS FURTHER COMPLICATE CONDENSER SELECTION WHILE IMPROVED DESIGNS AND AUXILIARIES GIVE BETTER PERFORMANCE WITH THE POSSIBILITY OF FURTHER GAINS. BY HOWARD W. LEITCH*

WITH A GROWING REALIZATION of the savings to be effected by a proper condenser installation and of losses sustained by poor design and operation, the selection of suitable condensing equipment has been given more consideration in the past few years than ever before.

Each installation design is being considered as a problem peculiarly related to the plant as a whole and inter-related to the general heat balance, the character of the service, and the general conditions of location. Sometimes fitting condensing apparatus into available space overshadows requirements of low investment and high vacuum for the least expenditure for pumping power. Units are now being designed to handle over one and a half million pounds of steam per hour, and the solution of the problems being met by a simple multiplication of factors of units now in use would be absurd.

CONDENSER DESIGN NOT NECESSARILY CHANGED BY STEAM EXTRACTION

Extraction of steam from the lower turbine stages, which is not being carried up to 25 per cent or 30 per cent of the total steam input, does not always allow of reduction of condenser size. For conditions where a large quantity of steam is bled from the turbine, selection of a condenser presents a peculiar problem. In designing for this condition very little consideration should be given to the nominal capacity of the machine and the calculations should be handled as if the condenser was to be selected for a low pressure turbine. Only the performance of that portion of the turbine below the last bleed stage should be considered in relation to the size of the condenser.

Performance of this portion of a unit is well known by the manufacturer, and with the information available it is possible to balance the cost of the condenser against the possible increase of output available from the machine. Where cool circulating water is abundant the possibilities for securing increased capacity and economy through the proper relation of condenser to the low pressure portion of the turbine shows a greater return on the investment than any other individual item of equipment in the entire plant. A slight increase in vacuum on a well designed turbine usually results in improved economies more than commensurate with the additional investment necessary to secure the increased vacuum.

RECENT INSTALLATIONS OF SINGLE PASS UNITS APPEAR TO ADVANTAGE

Surface condensers have almost monopolized the field for stations built on navigable waters and are standard for all large modern installations. Fundamentally, the greatest difference in the condenser itself is whether the circulating water passes directly through all of the tubes in parallel, or, whether it passes through a portion of the tubes in series with another portion, making the so-called multiple pass type. Up to within the last two years the use of two-pass condensers was almost universal, a small number of either three-pass or single-pass being used. Recently, however, single-pass condensers have been installed for some of the prominent new units and the reports of their operation are very satisfactory.

Recent investigations of the actual conditions of heat transfer and water flow throughout the tube banks of condensers in actual service have indicated such a poor division of work that impetus has been given to the designers to improve the average performance with the resulting less surface. Tube cleaning still presents a considerable field for investigation. Sand blasting, boiling and acid treatment are each used in certain installations but the big majority of condensers are still cleaned by shooting wire brushes or plugs through the tubes by air or water pressure.

Expansion joints, at one time considered essential between the turbine and the condenser, have gradually

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been abandoned. The necessity of extra joints and the deterioration of the expansion element itself, increased the possibility of air leaks so condensers supported on springs with permanently installed hydraulic jacks to adjust the spring tension have come into favor and seem to answer all the requirements of flexibility.

Search is still being made for metals with which to manufacture tubes which will withstand the ravages of tidal waters. Admiralty mixture, 70 copper, 29 zinc and 1 tin, is still the favorite metal. Certain installations abroad have been made of tubes with a composition containing 20 per cent to 30 per cent of nickel, but it will take several years to determine whether the extra life of this metal will warrant the necessarily high cost. As a general rule tube failures are found to be the combined results of many factors including composition, work performed, character of cooling medium and the methods of cleaning.

Reduction of tube size from the standard of one inch has not made much headway, although a few units installed within the last two or three years have made use of ⅞-in. tubes. Where the water is dirty, however, the increased liability to clogging seems more than to offset any theoretical gain in heat transfer of the small tubes. Metallic packing and the practice of rolling tubes into the tube sheets at one or both ends have also made little progress, although it is realized that in certain installations the electrolytic advantages of metallic contact are not to be ignored. A scheme inaugurated by one of the tube companies of installing a flexible metallic ring at the base of the regular packing, seems to give many advantages of metallic packing, at the same time retaining those of the old corset lace.

Variable Speed Pump Motors Meet Economy and Safety Requirements

Use of multiple speed circulating pumps has increased enormously so that from their being a rarity five years ago they are now practically universally used. Circulating water temperatures in more than half of the condenser installations have a seasonal variation from 32 deg. to 75 or 80 deg F., so the use of duplicate multi-speed circulating pumps affords attractive combinations for economy and safety. Pumps driven by alternating current motors are generally designed for not more than three speeds. Where direct current is available or steam driven pumps used, however, the amount of circulating water delivered can be constantly regulated for the best economy. The availability of small turbines with high economy and comparatively flat water rate characteristics added to the possible advantage of a complete independent source of power has caused some of the latest installations to adopt this character drive.

In the matter of air extraction apparatus the steam evactor is most commonly used and for a while seemed to be entirely supplanting the hydraulic vacuum and reciprocating dry air pumps. Its low first cost and economy of space with inter coolers using condensate have made this apparatus quite popular. There is, however, a growing tendency to dispense with the use of condensate, either for this service or for oil coolers, as not being able to justify the many complications.

Where the air discharge is likely to contain considerable vapor a hydraulic pump is superior to any other type since it is more economical than the evactor and due to its action as a jet condenser to condense the vapor does not lose capacity as does either an ejector or a dry vacuum pump under these conditions. Maintenance of its runners, however, presents a problem and its vacuum is limited to that corresponding to the hurling water temperature.

It has always been recognized that the most economical method of extracting air from a condenser is by the use of a reciprocating dry vacuum pump. It is reliable and the vacuum to be obtained is limited only by the pump cylinder clearances. On account of the amount of space it occupies, the number of its installations has been comparatively few but with the introduction of the vertical piston design this objection has been removed and an increasing number of the newer installations are making use of this design.

Augmentor Offers Future Possibilities of Better Performance

One feature of condenser design which offers possibilities seems to have been neglected. The augmentor which has been used to some extent in European practice would seem worthy of consideration even to a greater extent than has heretofore been attempted. Condenser tube performance could be greatly improved provided higher steam velocities were to be maintained throughout that portion of the condenser not devoted to air cooling. By the use of the augmentor and proper tube distribution the performance of the condenser would not be compromised by the necessity for adequate air cooling surface. The air cooler operating under reduced vacuum would of necessity also condense a considerable quantity of steam and should preferably be separated from the main condenser. In effect, this scheme of operation would be similar to the present two-stage steam jet air ejectors in which the intercondenser would be large and much greater volumes of gaseous mixture would be withdrawn from the condenser by the primary ejector.

Bled steam from the main unit could be employed in the primary ejector and preferably a hydraulic pump should be employed for removing the air and non-condensible vapor from the augmentor condenser. It is believed that by some such combination as this higher sustained vacuums will be possible with much less tube surface. Furthermore any possible reduction in the tube surface will permit improvements in the condenser for draining so as to approach a dry tube condition so essential to good performance.

Commenting on an article "Luminous Bacteria, the Smallest Lamps in the World" in the December Scientific American, the editor of that magazine says:

"Who has not read loose statements that the firefly or other luminous forms of life generate light far more efficiently than man does in his power plants?

"Granting that the overall efficiency of the best incandescent lamp is only ½ of 1 per cent, parallel calculations on 'cold light' forms of life demonstrate that the overall efficiency of some forms, such as luminous bacteria, is only twice as great. Thus, we are within hailing distance of Nature already. So man, who occasionally likes to belittle his own achievements, has not done so badly after all. Probably he can do better."

Condenser Improvements Benefit Entire Station

SINGLE PASS, DIVIDED WATER BOX, IMPROVED STEAM DISTRIBUTION, DEAERATING HOTWELLS, INTRODUCTION OF BOILER MAKE-UP AND IMPROVED CLEANING METHODS ALL ASSIST IN IMPROVED STATION EFFICIENCIES

DEVELOPMENT of the single pass condenser has done much to stimulate improved efficiency but, in spite of the tendency toward the use of the single pass unit, there is evidently little to choose between the two types if equally well designed. Fixed charges and operating costs of the circulating pumps must be considered. With an abundance of water and low pumping heads the single-pass type is favored, but with limited water, long tunnels and high pumping costs, the two-pass type has the advantage.

Up to the present, condensers, as measured by steam capacity, have kept pace with the growth of turbine sizes, steam flows ranging up to 500,000 lb. per hr. being handled in a single shell. Although larger units can be built, construction and installation difficulties place this as about the upper limit so that, even with improved designs to increase the unit steam capacity, there is a tendency toward the use of divided units for steam flows of 1,000,000 lb. per hr. and over which have been proposed. The double vertical condensers as installed at the Crawford Avenue station are admirably adapted to this practice.

NEWER STATIONS VERY CONSERVATIVE ON STEAM FLOW PER UNIT OF SURFACE

Steam flow per unit of surface ranges from 5 to almost 11 lb. per sq. ft. of condensing surface. This variation, however, can hardly be considered as a general tendency toward increased steam flow as several of the most recent stations are exceedingly conservative on this point. It is perhaps more significant to note that all plants which installed additional units after the original ones were in service some time increased the maximum steam flow per square foot from 7 to 30 per cent.

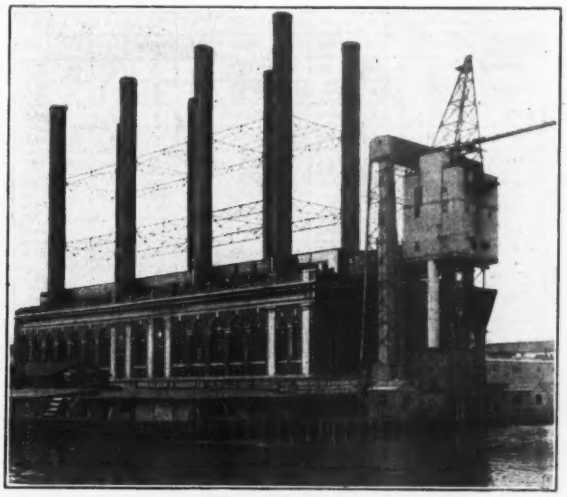
Taken under the same conditions of water load and equipment, it lends emphasis to the general statements of improved performance and efficiency. On some of the smaller units maximum steam flows of as high as 20 lb. per sq. ft. are reported. Without considering the turbine water rate curve and water conditions, however, such figures mean little as a basis of comparison. In the future they will mean less, as the demand increases for turbines having a relatively high overload capacity, as compared to the most economical load. Under small central station or industrial conditions carrying system loads, load factors are low but high peak capacity is necessary. It is but natural that condensers as well as turbines will be designed for peak loads under which efficiency is of minor consideration.

TUBE ARRANGEMENT IS SECRET OF EFFICIENCY

Development, or rather efficiency, is largely tied up in tube arrangement, various methods being utilized to obtain even steam distribution and eliminate ineffective tubes. Removing some of the tubes to form steam lanes, differential tube spacing, different tube sizes to control the flow of water through certain sections and provision for a steam belt around the tube bank are some of the methods used. Air-cooling sections, in some cases 25 per cent of the total, formerly placed on one or both sides of the shell seems to be gradually shifting to the center of the shell in order to allow steam entirely to surround the tube bundle and give more uniform steam flow to all sections.

Three recent designs are shown by tube sheet arrangements 18, 19 and 20. The last two utilize external air coolers, a practice which will undoubtedly increase in popularity as conditions make it necessary to reduce the size of the shell as much as possible.

Water-sealed expansion joints are used with the single vertical units utilizing an exhaust stack but have entirely disappeared on large horizontal units. Springs, usually adjustable with hydraulic jacks, are in general use, although Richmond makes use of a counterweight arrangement and a somewhat smaller unit in the south has been installed without condenser supports, the shell being hung from the turbine.



NARRAGANSETT STATION

NEW VERTICAL UNIT WILL BE SINGLE PASS

Relatively small shell sizes of the single-pass condenser makes the latter arrangement possible for medium-sized units. In fact there is a decided tendency toward the use of both vertical and horizontal single-pass condensers, the new double-shell, single-pass vertical unit designed for use with one of the new 100,000-kw. turbines probably being the most reliable indication of the trend of design for the larger units.

Three passes have practically disappeared, the units in the Fordson station being the only ones of importance built in recent years. It is not likely that the use of the jet condenser for central stations will increase because of complications involved in supplying the grade of feed water required with the high boiler ratings in use today. Both the Fordson and Narragansett stations can, therefore, be considered as special

condenser design being determined by external conditions.

Cleaning Facilitated by Divided Water Boxes

Divided water boxes are, however, becoming increasingly popular, not in a certain section but throughout the country as a whole. The facility with which slime and debris can be cleaned from the tubes while the machine is in operation is a decided advantage in many plants. By properly choosing the time, the cleaning can be accomplished with little or no drop in vacuum during the process.

Deaeration of the condensate in the condenser hotwell is undoubtedly the most pronounced change. Practically all types of deaerating hotwells will meet the demands of manufacturers of steel economizers, while guarantees of from 0.03 to 0.05 c.c. of oxygen per liter have been made. Introduction of make-up water to the main condenser is practiced at several plants and, when introduced at somewhat higher than vacuum temperature, deaeration results are good without affecting in any way the operation of the condenser.

Extraction Heaters Eliminate Importance of Condensate Temperature

Depression or undercooling of the condensate is of relatively small importance with the modern plant using extraction heaters. Modern condensers, however, show depressions of seldom more than 2.5 or 3 deg., due to the practice of having the condensate steam drop through a steam space. One recent installation even has a hand-controlled damper with which the flow of steam to the bottom of the condenser can be controlled. This allows regulation of the hotwell temperature with load and water temperature. Reheating-type hotwells, which are in effect small jet condensers supplied with exhaust steam, are in use and will bring the temperature so close to that corresponding to the vacuum that no difference can be detected.

Water velocities varying from 4 to 8 ft. per second show little change over those of previous years, indicating that proper velocities, which are controlled largely by pumping costs, have been closely determined. Velocities in single pass units do not noticeably exceed those used with multi-passing, although they show somewhat closer agreement between various installed units.

In all single-pass units a water-steam ratio of 100 to 1 or over is provided, corresponding to a temperature rise of from 9 to 9.5 deg. This is made necessary primarily by the limited temperature rise which must be maintained in order to give uniform steam distribution in a single-pass unit. Some of the newer designs have the condenser divided into four separate sections, each with its own vacuum pump.

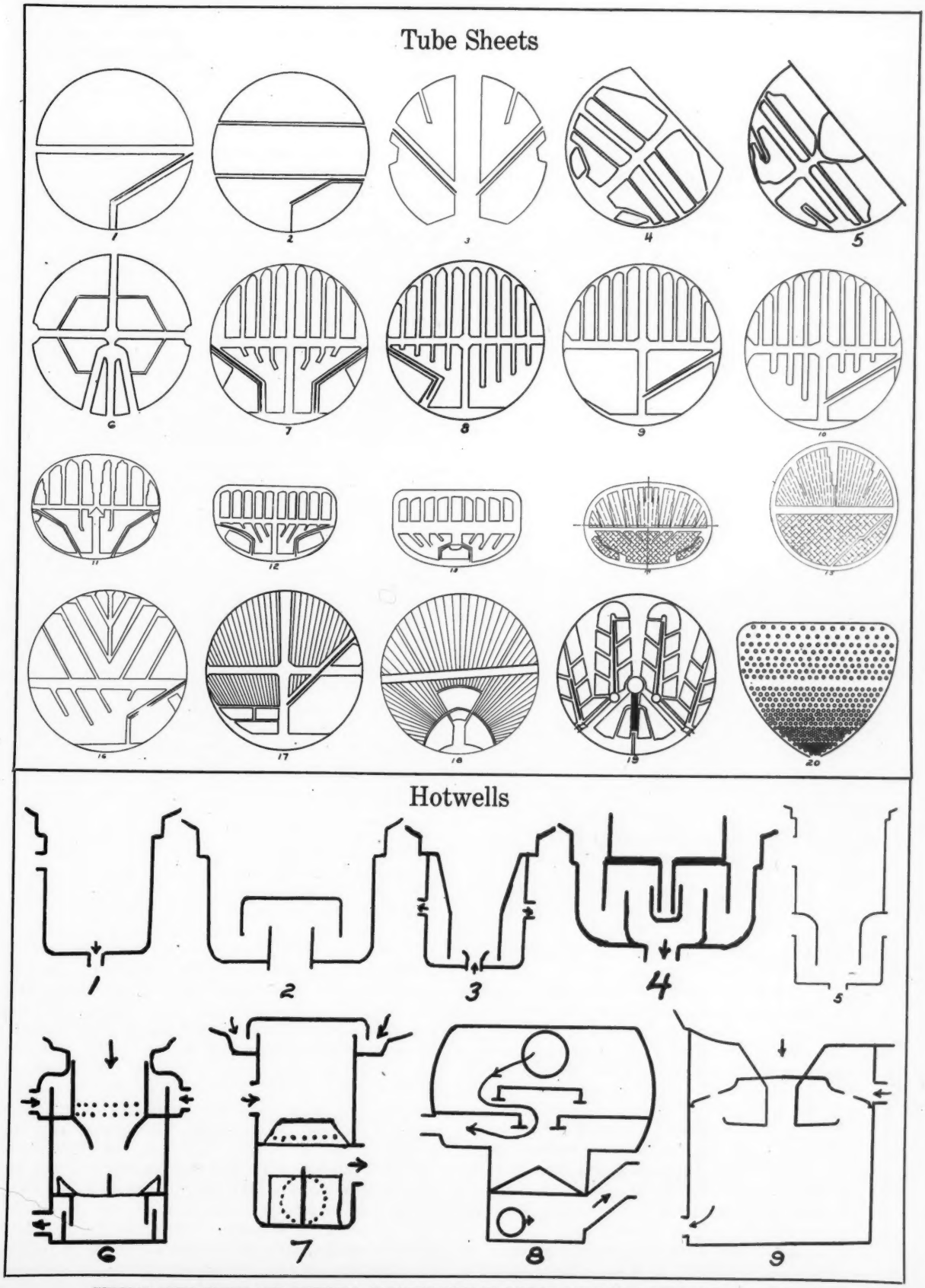
Water Velocities in Two-Pass Units Vary Widely

Two-pass units show considerable variation ranging from 7.6 up to 17.6 per sec. with corresponding water-steam ratios of 125 and 54. The average is well over 10 with plants located on middle western rivers showing a fair degree of uniformity as might be expected from the similarity of water conditions.

Cooling surface in square feet per kilowatt installed capacity has been steadily decreased, reaching low values of 0.95 at Trenton Channel for single-pass condensers and 1.065 at Columbia for the two-pass type.

CONDENSER DATA

PLANT	TURBINE NO	TURBINE RATING	NO. COND UNIT	TYPE	SURFACE EACH	SURFACE SQ.FT/KW	STEAM FLOW LB.PER HR.	STEAM FLOW LB./SQ.FT.	CONN. TO TURBINE	HOTWELL TYPE	HOTWELL TEMP. DEPRESS.	VAC. REF. 30"	WATER NO. OF PASS.	WATER WATER BOX	WATER TUBE VELOC.	WATER STEAM RATIO	WATER TEMP IN	WATER TEMP RISE	WATER SOURCE OF SUPPLY	TUBES METAL	TUBES DIA.	TUBES SHEET	TUBES PACKING	CLEANING METHOD	CLEANING FREQ.	CLEANING HR. REQ.	CLEANING MAN HR.
COLUMBIA	2	45,000	2	VERT	48,000	1.065	310,000	6.46	EXPJOINT	B	2	29	2	SINGLE	5.62	9.9	70	10.3	BIG MIAMI R.	ADMIRALTY	1	7	BOTTOM ROLLED TOP ALLEN	← NOT	NECESSARY →		
CRAWFORD	1 1	50,000 52,500	1 1	V. V.	56,000 64,000	1.12 1.22	420,000 374,000	7.50 5.76	RIGID R.	B B	3 3	28.5 28.6	2 2	3 3	5.23 5.3	9.5 9.3	70 70	10.2 10.2	CHICAGO DRAIN. CANAL	MUNTZ MUNTZ	1 1/8	4 5	BOT. ROLLED TOP ALLEN	(LANCING BACK WORKING PLUGGING	WKLY EVERY ANNUALLY	6 8 HR.	12
PHILO	2	40,000	2	V	45,000	1.125	300,000	6.66	E	A		29.5	2	DIVIDED	4.7	7.5	60	16.7	MUSKINGUM R.	ADM. A	1		FIBER	BACKWASH R.P. BILGE PUMP	3 TIMES DAILY		
TRENTON CHANNEL	3	50,000	3	HOR.	47,500	.950	475,000	10	RIGID	1	2	28.9	1	S.	6.6	10.5	60	9	DETROIT R	ADM.	1	17	ALLEN	RUBBER PLUG	1 MO.	2.5	88
RICHMOND	2	50,000	2	H.	70,000	1.40	500,000 400,000	7.15 5.72	R. R.	1/4	2.4 2.4	28.5* 28.5*	2/2	S/S	7.2 6.1	9.0 9.15	70 75	10.5 9.75	DELAWARE R.	M. A	1/1	3/8	ROLLED & METALLIC	R.P	1 WK.	10	50
KEARNY	3 2	35,000 40,000		H.	56,000 56,000 35,000	1.43 1.43 1.25	353,000 1015,000 300,000	7.40 8.36 8.20	R R R	3 2/4		28.5 28.45 28.66	2	D. D. D.	5.7 5.7 6.1	10.7 8.2 12.7	70 60 70	9.5 10.3 7.5	HACKENSACK R.	A.	1/1	1/8	CORSET LACE	R.P.	2 WK.	16	64
AVON	2	35,000	2	H.	42,000	1.2	350,000	8.33	R	1		28.5	1	S.	6.0	10.6	10	9	LAKE ERIE	M.	7/8	16	METALLIC-ROLLED END	WATER	NOT DETERMINED		
SOMERSET	1	32,000	1	H.	45,000	1.405	300,000	6.66	R	2		28.82	2	D	5.5	10.0	60	9.5	TAUTON R	A	1	12	CORSET FIBER LACING	R.P.	2 WK	10	20
NARRAGANSETT	1	35,000	1	V.	JET	——	350,000	——	R	——	——	28.7	——	——	——	9.5	60	23	NARRAGANSETT BAY	← SHELL LEAD LINED →				——	——	——	——
EDGAR	2	32,000	2	H.	45,000	1.405	300.	6.66	R.	1	2	28.7	2	S.	7.00	10.0	70	9.5	FORE RIVER	A.	1	10	CORSET LACING	R.P.	1 MO.	8	16
LONG BEACH	2 2	37,800 52,800	2 2	H.	55,000 75,000	1.455 1.42	300,000 400,000	5.46 5.33	R	4 4		28.72 28.75	2	D.	7.1 7.0	11.7 12.5	72 72	8.15 7.6	PACIFIC OCEAN	A	1 1	6 6	METALLIC ROLLED AND CORSET	COMP. AIR WATER JET SAND BLAST	TRYING DIFFERENT METHODS	1/2 1/4 1/2	8 48 300
SEAL BEACH	1	31,250	1	H.	45,000	1.43	380,000	8.39	R.	2		28.96	2	D	6.5	6.6	55	14.4	PACIFIC O.	A.	1	12	FIBER	NOT NECESSARY			
SUSQUEHANNA	2	30,000	2	H.	38,000	1.265	320,000	8.42	R	2	1	28.6	1	D.	7.2	10.0	70	9.9	SUSQUEHANNA R.	A	3/8	12	ROLLED AND CORSET	R.P.	1 MO.	12	24
CAHOKIA	3 1	30,000 35,000	3 1	H.	53,000 56,000	1.77 1.60	300,000 350,000	5.66 6.25	R R	1 & 3 3		28.6 28.6	2	D D	4.87 5.78	9.0. 8.72	70 70	10.9 10.9	MISS. R.	M.	1 1	3 & 9 3	ROLLED AND CORSET				
RIVERSIDE	1	20,000	1	H.	30,000	1.5	195,000	6.5	R	3	1	28.5	2	S.	5.0	8.22	70	11.6	MISS. R.	M.	1	3	ROLLED AND CORSET	R.P.	6 MO.		90
WAUKEGAN	2 1	25,000 30,000	1	H.	32,000 49,000	1.28 1.90	195,000 330,000	6.1 6.73	R R	3/3	5/3	28.5 28.5	2	S S	6.8 7.2	8.1 7.8	70	11.1 13.2	LAKE MICHIGAN	70-30 BRASS	1 1	15 19	ALLEN FIBER FIBER CORSET	R.P.	2 WK.	8	24 56
VALMONT	1 1	20,000 25,000	1 1	H.	30,000 30,000	1.5 1.2	310,000 332,800	10.19 10.92	R. R.	4 2		28.88 28.91	2	S.	5.9 5.8	8.67 5.9	60 60	11.1 11.6	VALMONT LAKE	BRASS M.	1 1	6 13	METALLIC ROLLED METALLIC	R.P.	YRLY.	8	32
HALES BAR	2	20,000	2	H.	34,000	1.70	235,000	6.9	R	1	2	28.75	2	D.	6.2	8.5	53	11.15	TENN. R.	M.	1	3+15	METALLIC	R. P.	10 WK.	16	64
BIG SIOUX	2	12,500	2	H.	17,000	1.36	120,000	7.06	R.	STORAGE TANK	1	28.5	2	D.	5.5	7.9	70	12.6	BIG SIOUX R.	A	1	6	CORSET LACE	R.P.	6 MO.	10	20
NEOSHO	1	15,000	1	H.	27,000	1.8	133,000	5.0	R	4		28.45	2	D	5.25	9.6	75	9.85	NEOSHO R.	A.	1	6	CORSET LACE	R.P.	4 MO.	8	32
DRESSER	3	20,000	3	H.	40,000	2	210,000	5.25	R	4	1	28.65	2	D	5.2	9.5.4	70	9.96	WABASH R	M.	1	6	FIBER	R.P.	1 WK. TO 3 MO.	16	16
EDGEWATER	1	20,000	1	H.	30,000	1.5	240,000	8.00	E	2	5	29.0	2	S.	7.6	8.3.5	70	11.4	LAKE ERIE	BRASS	1	16	CORSET LACE	WATER	DAILY	1/2	1/2
BARBADOES	2	20,000	2	H.	40,000	2.0	270,000	6.75	E R	4	2	29.5	2	D.	5.8	8.7	70	10.9	SCHUYLL R.	M.	1	16/8	FIBER	R.P.	6 WK.	8	16
PINE GROVE	2	12,500	2	H	24,000	1.92	125,000	5.21	R	1	3	28.9	2	D	4.1	9.2	60	10.35	SPRAY POND	M.	1	3	ROLLED AND CORSET	R.P.	2 WK.	8	32
IRON MT.	2	←			NON	CONDENSING →																					
BROTHERHOOD OF L.E. BLDG.	2 2	←			NON	CONDENSING →																					
FORDSON	2 3	12,500 30,000	2 2	H.	22,000 48,000	1.76 1.60	138,000 340,000	6.28 8.11	E R	1	4 4	28.5 28.5	2 3	S S	5.6 7.0	8.7 7.2	70 70	10.92 12.38	RIVER ROUGE	M. M.	1 1	1 2	CORSET METALLIC	R.P.	1 WK.	8	16 32
BETTENDORF	2	2,500	2	H	4,228	1.69	47,000	11.1	E	1	5	28	2	S.	7	6.0	70	15.9	MISS. R	70-30 BRASS	3/4	15	FIBER	R.P.	NOT DET.		
BAYONNE		←			NON	CONDENSING →																					



TYPICAL TUBE SHEET AND HOTWELL ARRANGEMENT IN USE OR DEVELOPED DURING THE PAST YEAR

By comparing actual steam condensing surfaces, exclusive of the air-cooling tubes, for plants in the same locality, improvements which have been made in this direction are more apparent. For instance, a 35,000-sq. ft. condenser with 6.8 per cent of the surface in an air cooler was installed in a Detroit plant 10 yr. ago under a 20,000-kw. turbine, actually 1.40 sq. ft. of steam condensing surface per kilowatt. The modern 47,500-sq. ft. units with 25 per cent air-cooling surface have but 0.715 sq. ft. per kw. capacity, practically half the value used a few years ago.

This is perhaps the most reliable measure we have of increased condenser efficiencies, being as it is, a direct comparison of condensers built by the same manufacturer for the same company under the same load and water conditions.

CONDENSER AUXILIARY DATA

PLANT	CONDENSER SURFACE	SOURCE AUX. ELEC. POWER	CIRCULATING PUMP: NO. INSTALLED	NO. OPERATED	CAPACITY: EACH	CAPACITY: TOTAL	G.P.M. PER KW.	TOTAL HEAD	DRIVE	WATER SCREENS	HOTWELL PUMP: NO. INSTALLED	CAPACITY: LB. PER HOUR	CAPACITY: %COND. CAP	TOTAL HEAD	DRIVE	EJECTORS: NO. OF UNITS	CAPACITY: CU.FT. FREE AIR	CAPACITY: TEMP	CAPACITY: PRESS. (ABS.)	CU.FT. PER M.K.W.	STEAM: PRESS. ABS.	STEAM: CONSUMPTION	STEAM: % TOTAL STM. FLW.	COOLING WATER	HYDRAULIC AND R.D.V. PUMPS: TYPE	NO.	CAPACITY: CU.FT. FREE AIR	CAPACITY: TEMP	CAPACITY: PRES.	CU.FT. PER M.K.W.	MOTOR HP.	%TOT. TURB. RATG.
COLUMBIA	40,000	SHAFT GEN.	2	2	35,000	60,000	1.33	27'	MOTOR	TRAVELLING	2				MOTOR										HYD.	4	28			622		
CRAWFORD	35000 75000 65,000	SHAFT GEN.	2	2	40,000 40,000 35,000	80,000 " 70,000	1.60 1.38		M. T.	T.	2 3				M. M.	6 1 2	1.99 40 40	70 70 70	.1 .1 .1	13.80 Ao .76	220 200 180	6600 2400 2000	1.570 .872 .853	CONDEN. & BRKR. KW/MILE	HYD HYD	4 1	40 18.9	70 78	1" 1.5	.878 .930	200 89	3.79 .917
PHILO	45,000	TRANS.	2	2	33,000		1.33	16	M.	T.	2	250,000	116.8	235	M.	2	48		.5	1.20				CONDENSATE								
TRENTON CHANNEL	47,500	H.TURB.	2	2	60,000	100,000	2.00	26	M.	T.	2	600,000	126.2		1-M. 1-TURBINE										R.D.V.	1	35x18	VERT		66	.098
RICHMOND	70,000	TRANS.	2	2	60,000	100,000	2.00	19	M.	T.	2				M.	2	50	70	1	1.00	165	1800	AK.400	COND. & FILT. WAT'R.	HYD	2	33	70	1.5	.660		
KEARNY	50,000	TRANS.	2	2	38,500	76,000	2.17 1.40	41	M.		2	500,000	AV. 132.0	175	1-M. 1-TURBINE	2 1 2	80 80 116	87 70	1.5 1.5 1.5	2.24 2.62 2.40	265 150 518	3730 2400 2660	.766 .574 .804	COND.	HYD HYD	1 2	48.5 66.0	70 70	1.5 1.5	1.395 1.620	75 75	.187 .197
AVON	42,000	TRANS.	2	1	43,500	74000	2.03	18	1-M. 1 DUAL	T.	2	430,000	120.0		1-M. 1-DUAL	3	30	70	1	.86	240	1635	.467	COND. OR SERV. WTR.								
SOMERSET	45,000	SHAFT GEN.	2	2	40000	60,000	1.87		M.	T.	2	330,000	110.0		M.	2	60	70	1	1.88	150	2300	.766	COND								
NARRAGANSETT	JET	H.GEN.	2	2	18,000	36,000	1.03		M.	T.						2	187	70	1	5.63	190	6000	1.715	CITY WATER								
EDGAR	45000	SHAFT GEN.	2	2	39,000	60,000	1.87	31.5	M.	T.	2	375000	125.0	225	M.										R.D.V.	1	35x18	VERT		60	.190
LONG BEACH	30,000 75,000	SHAFT GEN.	2 2	2 2	44,000 62,500	70,000 100,000	1.89 1.89	24 25	M. M.	T. T.	2	500,000 650,000	166.6 167.5	155 160	M. M.	2	96 107	70 70	1.6 1.8	2.59 2.03	190 190	28.00 3200	.993 .800	COND. + SALT W.								
SEAL BEACH	45,000	SHAFT GEN.	2	2	35,000	50,000	1.59	25	M.	T.	2				M.	2	92	70	1.5	2.94	145	2400	.632	COND.								
SUSQUEHANNA	45,000	TRANS.	2	1	32,500	32500	1.08	27	1-M. 1-DUAL	T.	2	400,000	125.0	150	M.	2	40	70	1	1.33	180	1600	.500	COND.								
CAHOKIA	53,000 36,000	H.TURB.	2	2	33,000 30,600	59,000 61,000	1.8 1.79		M. M.	T. T.	2	900,000	AV. 125.0		M. M.										R.D.V.	1	33x24	HORIZONTAL		50	.124 .106
RIVERSIDE	30,000	TRANS.	2	2	21,000	32,000	1.60	27	M.	T.	2	300,000	159.0	180	M.	2	20	70	1	1.0		900	.512	COND.								
WAUKEGAN	32,000 32,000	TRANS.	1 1	1 1	35,000 50,000	35,000 50,000	1.44 1.43	26 25	M. M.		2	300,000	154.0		M. M.	2 2	60 68	87 87	1.5 1.5	2.00 1.94	265 265	2000 2230	1.025 .674	COND. COND.								
VALMONT	30,000	TRANS.	2 2	2 2	18,000 18,000	36,000 36,000	1.80 1.44	25 25	1-M. 1-DUAL		2 2	300,000		100	1-M.-1-TURB. 1-M.-1-TURB.	1	38 30	70 70	1.5 1	1.9 1.2	190 190	1400 1150	.666 .395	COND. COND.	HYD.	1	11.93	70	1.5	.546	50	.187
HALES BAR	34,000 34,000	TRANS.			—	40,000	2.00	12	GRAVITY		2	250,000	106.2	750	M.	2 2	40 44	70 70	1 1	2.0 2.2	140 130	1800 2260	.765 1.400	COND + RIVER W.								
BIG SIOUX	17,000	TRANS.	2		11,000	19,000	1.52	11-23	M.	T.	2	300,000	125.0	300	M.	2	68	70	1.5	5.45	190	260	2.162	COND.+ RAW W.								
NEOSHO	27,000	TRANS.	1	1	24,000	26,000	1.73		DUAL	STAT.	2	220,000	163.0	130	M.	1	48	70	1.5	3.20	215	1500	1.111	COND.								
DRESSER	40,000	TRANS.	2	2	25,000	48,000	2.00	21.5	M.	T.	2				M.	1	38	70	1	1.90	190	1600	.761	COND + RAW W.								
EDGEWATER	30,000	TRANS.	1	1	40,000	40,000	2.00	12	DUAL		2	287,600	120.0	135	DUAL	1	17	70	1	.85				COND + RAW W.	HYD	1						
BARBADOES	40,000	TRANS.	2	2	24,000	45,000	2.25	16	M.	T.	2	400,000	148.0		M.										HYD.	2	30	70	1.5	1.666	75	.178
PINE GROVE	24,000	H.TURB.	2	2	13,750	24,000	2.08		M.		2				M.	1	20	70	1	1.60		900	.720	COND.								
IRON MT.																																
FORDSON	22,000 48,000	TRANS	2 2		15,000 30,000	28,000 55,000	2.24 1.83	13.5	M. 1-M.-1-TURB.	T. T.	2 2	200,000 [illegible] 350,000	149.0 138.0		M. 1-M. 1-TURB.	1 2	60	80	2"	2.00	130 150	2000	.513	COND.								
BROTHERHOOD OF L. E. BLDG.																																
BETTENDORF	4,280	TRANS.	1	1	5600	5600	2.24	43	M.	T.	1				M.	1	13	95	2	5.19	145	650	1.381	COND.								
BAYONNE																																

Turbine Extraction Under Usual Conditions Does Not Materially Reduce Condenser Size

Under various water conditions other plants range from 2 sq. ft. per kw. down, none of the more recent large plants exceeding a value of 1.43. Modern extraction turbines in some cases allow a slight reduction in condenser size, although nowhere in relation to the reduction that has taken place. Theoretically a 1500-lb. regenerative cycle at 1500 lb. pressure would require about 47 per cent of the total steam to heat the feed water to its maximum value. The 10 to 15 per cent, which Kearny, for instance, actually uses, would come far from making material changes.

Until some superior method of water purification or tube cleaning is developed it is not likely that the large 1-in. tube will be displaced from popular favor. Because of higher heat transfers and water distribution advantages $\frac{7}{8}$ and $\frac{3}{4}$-in. sizes are occasionally used where water conditions are good and the danger of stoppages and clogging relatively small.

Metals Used for Tubes Receives Much Attention

Experimental work with various alloys has been and is being carried on but because of the length of time required for accurate determinations, nothing definite has been determined. Muntz metal and Admiralty mixture are still generally used, although four plants using fresh water at widely scattered parts of the country report satisfactory service from brass. Aluminum-bronze and a high nickel content copper-nickel alloy give promising indications. In sea water containing entrained air a wide range of copper alloys is susceptible to corrosion at the same rate as 70-30 brass. Temperature plays a considerable part, and it is interesting to note that corrosion is increased for 80-20 copper-nickel and copper tubes with an increase of temperature but for 70-30 brass, the rate of corrosion decreases.

Tube packings show little signs of standardization, although the old-style corset lacing appears to be at least holding its own in spite of new types and the practice of rolling or expanding one end of the tube. One company rolls both ends of the tubes and uses one floating tube sheet to take care of expansion.

Practice in regard to condenser leakage varies, depending primarily upon the condition of the water and its effect on the boiler concentration. Many plants pay no attention until it exceeds the make-up required. In general for bad waters leakages of 5 gal. per hr. or

over should be corrected. Packing leaks can be largely eliminated by proper maintenance but holes in the tubes are not such a simple problem and require constant care. Electrolitic leakage meters are in service and are useful in detecting small leaks.

For tube cleaning rubber plugs shot through the tubes by air or high pressure water have come into almost universal use. High pressure water jets, wire brushes, sand blasting, chemicals and baking are still used, however, and that the problem is far from being definitely settled is shown by the fact that a number of companies are still carrying on experimental work along this line.

Cleaning periods vary from once a day to once a year, depending upon water conditions. Some of the plants stop for cleaning when the vacuum drops a certain increment but the majority clean periodically at a convenient time interval determined by operating and load conditions.

Chlorine with a concentration of about 0.45 parts per million has been found effective in the elimination of algae growing in waters containing sewerage. The method, however, is a prevention rather than a cure, as the chlorine kills not the algae, but its food and is effective only on tubes initially clean. Baking the condenser and then flushing out the cracked scale has been carried on successfully without apparent damage to the condenser or packing but the method is not widely used.

Vertical units are usually arranged so that the bottom compartment can be pumped out periodically and the unit backwashed. Floating debris will collect in the top of the first pass and the baffle is ordinarily constructed as a damper, which can be opened to bypass or flush this out through the discharge pipe. Traveling screens, which are, of course, standard equipment in all cases, eliminate the larger pieces.

Although no phenomenal changes have taken place it is felt that the gradual improvement in condenser performance during the past year has been a real accomplishment directly benefiting turbines and boilers, simplifying feed water equipment and decreasing investment charges.

Efficient Auxiliaries Help Condensers

MOTOR DRIVE, HIGHER VOLTAGES, VARIABLE SPEED MOTORS, VERTICAL PUMPS AND AN IMPROVED DRY VACUUM PUMP ALL HAVE BEARING ON CONDENSER DESIGN AND SELECTION

DUPLICATION of units, general acceptance of motor drive, variable speed circulating pump motors and the introduction of a vertical reciprocating vacuum pump characterize condenser auxiliary development.

Both circulating and condensate pump practice show a decided trend away from the steam driven to the motor driven unit. Alternating current voltages of 2200 v. for both pump motors is common in the larger and newer stations. Circulating pumps almost invariably installed in duplicate, whether with a divided water box condenser or not, are generally of reduced capacity, so that both pumps are used at full load. A few isolated cases of duplicate pumps, each of full capacity and of single units, occur but they are the exception rather than the rule.

Sources of auxiliary power for these essential auxiliaries are fairly well divided between shaft generators, house turbines and transformers. Voltages of 440, 550 and 2200 are in use, the newest stations all favoring the latter. In addition to the duplicate units, there is a decided trend toward the use of variable speed motors, usually the wound rotor type, while practically all use automatic methods of restarting the motors or switching to another power supply in case of interruption. Not over 20 seconds are required for this change.

STEAM TURBINES HAVE NOT BEEN ENTIRELY ELIMINATED

Steam turbines, of course, still find considerable application either for dual drive or as a drive for one of the duplicate pumps, while direct current is used in the Trenton Channel plant and has many points in its favor. One large plant nearing completion will use turbines entirely.

Condensate pumps are invariably installed in duplicate, each with well over 100 per cent capacity as determined by the steam flow to the condenser. Steam turbine drive is distributed about the same as with the circulating pumps with motors considerably in the majority. Squirrel cage motors are by far the most widely used, although a fair representation of wound rotor and double squirrel cage types are found. Three recent stations, Kearny, Long Beach and Edgar, make use of the latter.

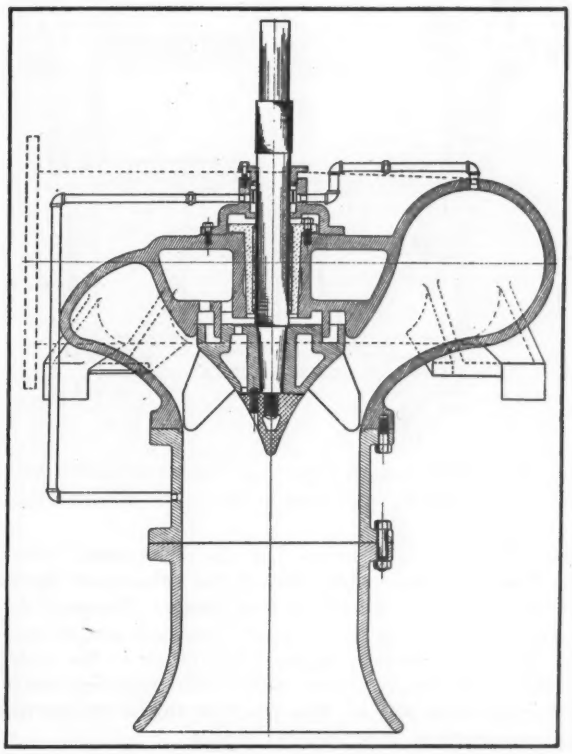


FIG. 1. VERTICAL CIRCULATING PUMPS OFFER ADVANTAGES FOR CERTAIN CONDITIONS

Horizontal two-stage condensate pumps are the most widely used. Vertical pumps are not so common, although the recent introduction of new vertical designs may influence this later. Perhaps the most interesting development in the pump field is the introduction of a new vertical circulating water pump of decided advantage in reducing the suction lift in plants operating where the tides or river flows cause considerable changes in water levels. Further, considerable space saving is accomplished and the pump can be installed below the floor level, allowing the condenser to be set lower to take advantage of the barometric seal at all times.

The total head against which the hotwell pump operates varies considerably in the various plants due to the different methods of heat balance. Some plants pump direct to a surge tank, some pump through the

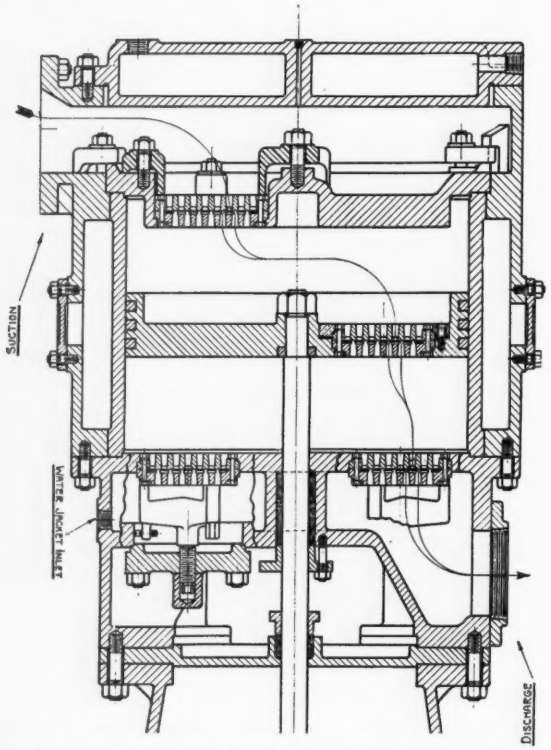


FIG. 2. A NEW ROTATIVE DRY VACUUM PUMP GIVING TWO STAGES IN A SINGLE CYLINDER IS IN USE IN TWO STATIONS

ejector coolers and various heaters, to an open heater or deaerator, while some deliver the condensate direct to the suction of the boiler feed pump. The only decided change seems to be away from the use of condensate in the ejector coolers, particularly in the intercooler. Raw water, filtered water and circulating water are being used instead, the latter arrangement offering the simplest and most reliable supply.

Three-Stage Air Ejector Gives Better Economy

Steam jet air ejectors still remain the favorite method of air removal. Two stages is standard practice in this country, although there has been some development of the three stage type as offering better economy. Economy is, however, not the reason for the wide application of ejectors, rather it is the simplicity, small space requirements and low maintenance and it is doubtful if small increases in efficiency would do much to increase its application.

From the standpoint of power economy, the hydraulic vacuum pump is more efficient and there seems to be a tendency to install a unit of this type in parallel with ejectors and use the latter as standby equipment. Various types of equipment cannot be compared by shop tests handling free dry air because of the different methods of operation. The hydraulic vacuum pump has the disadvantage of requiring cooler water than ejectors and furthermore, the vacuum obtainable is limited to that corresponding to the water temperature. Its action, however, is similar to a jet condenser and vapor finding its way through does not affect its air handling capacity to the extent that it does an ejector.

Many Plants Favor the Use of the Reciprocating Unit

Reciprocating vacuum pumps are not affected by water temperatures, the vacuum obtainable being limited only by cylinder clearance. Several large stations depend upon this type entirely, two of them, Edgar and Trenton Channel, having installed the new vertical single cylinder, two-stage type. One of the serious objections to the reciprocating pump was the space required, which has been materially reduced by the vertical design. Installed motor capacity for the unit at Edgar station is about 0.12 per cent of the turbine rating and it is claimed that the average power consumption should not exceed 30 hp. for a turbine unit of 30,000 kw.

External Air Coolers Not in General Use

Capacities of vacuum pumps depend, to a large extent, upon the efficiency of the air cooling surface. External coolers are used to some extent to increase the capacity of the vacuum pumps and reduce the size of the main condenser shell. The principal objection seems to be to the possibility of increased air leakage without reducing the total surface required. Practically all the air received is leakage, as the percentage entering with the steam is small. The general opinion seems to be that the size of the unit should have little to do with the total air removed and that a value of 5 to 6 cu. ft. per min. represents good practice.

With improved condenser performance the auxiliaries, at least the circulating and vacuum pumps become of increased importance when selecting the condenser. In spite of their importance, however, there is little possibilities of important changes beyond refinements of design and arrangement taking place.

Here is something that sounds impossible but, according to an engineer friend of ours, is quite practicable.

Not infrequently the glass front of a meter will get shattered and, unless the "face" is promptly replaced, the meter will suffer impairment from ingress of dirt and dust.

When a new glass front is unobtainable on short notice, cut out of cardboard the shape desired; hold this pattern on the glass; then, with the pattern, the glass, a pair of scissors and your hands, all under water, the glass can be readily shaped by a gradual snipping process.

Electric Generator Practice

SIZES USED. VOLTAGES AND METHODS OF VOLTAGE CONTROL, PRACTICE IN FURNISHING CURRENT FOR HOUSE SUPPLY

THAT THE INCREASE in size of generating units has kept pace with the increase in size of other elements of the modern power plant is readily seen from a glance at the accompanying tabulation of generator data. As a matter of fact, the electric generator is not necessarily the limiting factor in the growth of the turbo-generator. A few years ago generators of 35,000 and 40,000-kw. capacity were considered large. Today, such units are quite common and a generator of 90,000-kw. capacity is actually under construction. Even larger turbo-generators are under construction but these are mostly cross-compound or triple-expansion units having more than one generator so the individual generators are smaller than the 90,000 kw. machine referred to, which is to be installed at the Long Beach station in California.

Generator construction has undergone no radical change during the past few years. The standardized form of high-speed alternator, having a cylindrical rotor and carrying the field winding in slots distributed over its entire surface is invariably used. Owing to the great stresses associated with the high peripheral speeds used, the entire rotor, including the extensions constituting the shaft is often made from a single piece of steel. In this manner a maximum of rigidity is secured. In the larger machines, peripheral speeds of the order of 25,000 ft. per min. are employed. This, however, is about the limit at the present time. Any discovery or

DATA ON ELECTRIC GENERATORS

PLANT	MAIN GENERATORS								EXCITATION			REMARKS
	TYPE	SPEED	CYCLES	PHASES	VOLTAGE	CAPACITY MAIN UNITS	TYPE HOUSE SUPPLY	VOLTAGE HOUSE SUPPLY	SIZE EXCITER	VOLTAGE	DRIVE	
COLUMBIA	T.A.	1800	60	3	13,200	48000 KV.A.	SHAFT GENERATOR	2300	270 KW.	250	DIRECT	
CRAWFORD	T.A.	1800 1200	60	3	12,500 12,800	6,000 TO 90,000	SHAFT GENERATOR	2300		250	DIRECT	
PHILO	T.A.		60	3	11,000	44,500 KV.A.	TRANSFORMER	2300	250 KW.	250	DIRECT	
TRENTON CHANNEL	T.A.		60	3	12,200	62,5000 KV.A.	HOUSE TURBINE	2300 A.C. 250 D.C.	250 KW.	250	DIRECT	TRANS. INSTALLED FOR EMERGENCY
RICHMOND	T.A.	1800	60	3	13,800	62,500 KV.A.	TRANS. ALSO EMERGENCY HOUSE TURBINE	2300	250 KW.	250	DIRECT	
KEARNY	T.A.	1800	60	3	13,800	39,200 KV.A. 43,750 KV.A.	TRANSFORMER	2300	250 KW.	250	DIRECT	
AVON	T.A.	1800	60	3	13,200	43,750 KV.A.	TRANSFORMER	2300 440			DIRECT	
SOMERSET	T.A.	1800	60	3	14,000	30,000 KW.	SHAFT GENERATOR	2300	1-175 KW. 1-200 KW.	200	MOTOR & TURBINE	GENERATOR NORMALLY EXCITED BY DIRECT CONNECTED EXCITER
NARRAGANSETT	T.A.		60	3	11,000	35,000 KW.	TRANSFORMER	2300			DIRECT	
EDGAR	T.A.		60	3	14,000	37,500 KV.A. 3,150 KV.A.	SHAFT GENERATOR	2300	175 KW.	250	MOTOR & TURBINE	
LONG BEACH	T.A.	1500	50	3	11,000	50,000 TO 90,000 KW.	SHAFT GENERATOR	2300	175 KW.	250	TURBINE	
SEAL BEACH	T.A.	1800	60	3	13,200	37,500 KV.A.	SHAFT GENERATOR	2400	200 KW.	250	DUPLEX	
SUSQUEHANNA	T.A.	1800	60	3	13,200	30,000 35,000	TRANSFORMER	2300 230/115	200 KW.	250	DUPLEX	
CAHOKIA	T.A.	1800	60	3	13,800	35,000 KW. 40,000 KW.	HOUSE TURBINE	2300	150 KW.	250	DIRECT	
RIVERSIDE	T.A.	1800	60	3	13,200	25,000 KV.A.	TRANS. ALSO EMERGENCY HOUSE TURBINE	440	110 KW. 1-200 KW.	250	DIRECT	
WAUKEGAN	T.A.	1800	60	3	12,000	27,200 KV.A. 38,000 KV.A.	TRANSFORMER	440	200 KW.	250	DIRECT	
VALMONT	T.A.	1800	60	3	13,800	25,000 KW.	TRANSFORMER	440 220	175 KW.	250	DIRECT	
HALES BAR	T.A.	1800	60	3	13,200	25,000 KV.A.	TRANSFORMER	2300 440		250	DIRECT	
BIG SIOUX	T.A.		60	3	6,600	13,600 KV.A.	HOUSE TURBINE	550				
NEOSHO	T.A.	1800	60	3	12,000	15,000 KW.	TRANSFORMER	440	125 KW.	250	DIRECT MOTOR	
DRESSER	T.A.	1800	60	3	13,200	25,000 KV.A.	TRANS. ALSO EMERGENCY HOUSE TURBINE	2300 440	125 KW.	250	DIRECT	
EDGEWATER	T.A.	1800	60	3	6,600	25,000 KV.A.	TRANSFORMER	440	100 KW.	250	DIRECT	
BARBADOES	T.A.	1800	60	3	13,900	25,000 KV.A.	TRANSFORMER	2300	100 KW.	250	DIRECT	
PINE GROVE	T.A.		60	3	12,000	12,500 KW.	HOUSE TURBINE	2300	100 KW.	125	DIRECT	
IRON MT.	T.A.		60	3	13,200	5,000 KW. 750 KW.			100 KW.	230	TURBINE	
FORDSON	T.A.		60	3	13,200	30,000 KW. 12,500 KW.			500 KW.		TURBINE	
BROTHERHOOD OF L.E.	D.C.		60	3	250	2000 KW.					TURBINE	
BETTENDORF	T.A.		60	3	2,300	2,500 KW.					DIRECT	
BAYONNE												BOILER PLANT ONLY NO ELECTRICAL FEATURES

T.A.- TURBO ALTERNATOR

development that would permit of an increase of 10 per cent would at once allow the possible size of the unit to be increased approximately 33 per cent, since the possible largest size varies approximately as the cube of the speed.

Some idea of the size of modern electric generators may be obtained from the following weights of a 62,500-kv.a., 6-pole, 0.8 power factor, 1200-r.p.m., self-ventilated unit installed in the Hudson Avenue Power Station in Brooklyn; rotor 205,000 lb.; stator 205,000 lb.; shields, etc., 25,000 lb.; total, not including base, pedestals or bearings, 435,000 lb. There are some 41,250 lb. of copper in the machine. The stator has 37.6 miles of insulated wire, and the rotor 4.5 miles.

Many interesting manufacturing processes have been developed for constructing alternators of these sizes, one of the most interesting perhaps, being the milling of the slots in the large rotors. The cutters employed for this work have been developed to their present degree of perfection by little inventions from time to time during the past few years, such as methods of securing cutter teeth in place and removing them quickly. At the same time great improvements have been made in the treatment of the steel used in the teeth. The result of all this improvement is that the quantity of material now removed in a given time is practically twice that of a few years ago; at the same time, the cutters themselves require much less attention.

In winding modern generators of this kind, nine insulated leads are often brought out instead of the usual six. Of the three leads per phase, one goes to neutral and one to each of the two groups of three circuits comprising each phase. The arrangement permits the insertion of the current transformers used with the balanced relay system for generators, also the insertion of a differential current relay at the line end of each phase of the winding.

Generator voltages it will be noted from the table are standard in the neighborhood of 13,000 to 14,000 v. There are, as in the case of Big Sioux and Edgewater a few stations using 6600 v., but otherwise, even in some of the industrial power plants listed, voltages above 11,000 are used. This not only results in a lower amperage per slot in the generator but also permits the use of a sufficient number of slots.

Sixty-cycle machines are used almost exclusively. In the stations considered in this analysis, only one used another frequency. This is the Long Beach station, which generates at 50 cycles instead of 60. The question of speed is closely related to that of frequency and it is because of our standard frequency of 60 cycles per second that our turbo-alternators run at either 1200 or 1800 r.p.m. In this respect 60 cycles is perhaps not as suitable as 50 cycles since 50 cycles permits of synchronous speeds of 1500 and 3000, which in turn permit the use of smaller machines for a given output.

House Supply

One of the most important things in the design of generating stations that has occupied the minds of the designers and operators during the past few years has been the question of house supply, for this is intimately associated with the question of heat balance. In the modern station it has become the practice to drive most of the auxiliaries by motors, since the exhaust steam for feed water heating which was formerly supplied by these steam-driven auxiliaries, is now supplied, more conveniently and economically by extraction steam from the main generating unit. This being the case, the question arises, from what source should the electricity for running the electrically-driven auxiliaries be obtained?

RIVERSIDE STATION OF THE UNITED LIGHT AND POWER CO., DAVENPORT, IOWA

There are many factors entering into the problem, the most important being the purpose for which the station is designed, that is, whether it is to supply a base load, a system load or for standby service only.

In general there are six sources of electric power for the supply of the auxiliaries in addition to a number of special methods. These are as follows:

Main bus bars through transformers.
House turbines.
Shaft generators.
Transformers connected to the generator leads.
Supply from another station by means of a feeder not directly connected to the main bus bars.

Direct current with storage battery reserve.

In practice it is seldom that the auxiliary power supply is confined to any one of the above methods.

Of these methods, the simplest, and also the cheapest both as regards first cost, maintenance and operation, is that where the power is taken from the main bus through transformers. It is rugged, and no method is more economical. Its great drawback, however, is that system disturbances are reflected into the auxiliary supply at the very time the operation of the auxiliaries is most required. For this reason it is not used except where another good emergency source of power is available. Where it is used alone, the essential auxiliaries, such as the boiler feed pump and the condensate and circulating water pumps are equipped with a dual motor and turbine drive.

In the house turbine method, one or more relatively small turbo-generators are provided for the auxiliary power supply. This method has the advantage of not being affected by system disturbances, but it has a number of disadvantages which have limited its general adoption. The house turbine lends itself well to obtaining heat balance since the exhaust steam can be used in heating the boiler feed water, but its use entails many complications, both electrical and mechanical. Furthermore power cannot be generated as economically by the house turbine as by the main generator.

In many cases, however, the house turbine is used only as an emergency source of supply, the power for the auxiliaries being supplied, normally, by the main generators. In this case it is often kept as a stand-by set and used to start the station from a "cold" state. On account of their infrequent use, such sets may be operated non-condensing since they are never in use for any extended length of time, and the efficiency of operation is unimportant.

An extension of the house turbo-generator idea is new in the so called auxiliary or shaft generator which has made its appearance during the past few years. With this arrangement a separate alternator is provided for supplying electrical energy to the auxiliaries but instead of driving it with a separate steam turbine, it is driven by the main turbine itself. This provides an exceedingly satisfactory source of auxiliary supply since the power is generated by the most efficient prime mover in the station. Furthermore it permits unrestricted use of the regenerative cycle which is generally conceded to be satisfactory and economical. In some cases where this method of auxiliary supply is being used, the auxiliary generator is a 250-v. direct current machine supplying not only direct current for the auxiliaries but also for excitation of the main unit. It is therefore in this case, nothing more than an overgrown direct connected exciter. Direct current is well suited to operating auxiliaries since the direct current motor permits of an easy means of speed control.

Only a few of such direct current shaft generators have been installed, however. In all other cases it is an alternating current machine. The use of the shaft generator in this case complicates matters in that it renders the use of the highly desirable direct connected exciter difficult. In the case of cross compound turbo-generators, however, the auxiliary generator can be driven by one of the elements while the other carries the exciter which is made large enough to furnish excitation for the complete unit.

In some stations the house supply is derived from step down transformers connected between the main generator and the main oil circuit breaker, so that in event of this breaker opening due to trouble on the main bus, excitation will not be lost or interrupted.

The voltage used for the supply of auxiliaries, it will be noted from the table, is practically standardized at 2300 v., that is, for all of the larger motors. For small motors under, say, 40 or 50 hp., 440 v. is still used. Some of the smaller stations also use 440 v. for all of the auxiliaries. In general 3-phase current is used for the motors, for the lower voltage machines as well as the 2300-v. units.

Voltage Regulation

Voltage regulation in many of the newer stations is being accomplished by means of rheostatic type regulators which have been developed during recent years. When a station is on hand operation, the field is manipulated to keep a constant alternating current voltage, and the exciter is kept at constant voltage. Therefore if a regulator operates this rheostat through the medium of a motor, the station functions the same as if it were on hand operation.

Heretofore the difficulty with a regulator that operated the field rheostat directly has been the sluggishness and the inability to prevent hunting when the rheostat was operated at high speeds due to the inertia of the moving parts. These difficulties have been overcome, however, by the rheostatic type regulator now being used.

In some stations where all the main generators have direct connected exciters, stable operation is secured by means of a novel combination of exciter and generator field rheostats. With this arrangement the exciter is operated throughout its stable voltage range and the resistance is inserted in the generator field for low voltage. At the Hell Gate Station in New York, for instance, the first plate of the rheostat is divided up into three sections, the face plate of the rheostat is divided up into three sections. The first 38 steps operating in the exciter field bring the exciter voltage to a predetermined minimum stable operating condition. From this point or over the middle section, the generator rheostat is in operation, and as soon as the generator rheostat is cut out, the exciter voltage is raised by 180 steps in the exciter. The combination is designed for motor operation.

Generally, however, in large city central stations supplying power from the generator bus bars at generator voltage through a multiplicity of feeders, it is seldom necessary to resort to automatic voltage regulation, because the sudden changes in load are small in proportion to the generator capacity.

Six hollow head pistons were recently repaired in a southern utility plant, after being worn beyond usability, by adding manganese bronze to the cast-iron to replace the metal worn away, then turning down to size. The metal added by the oxy-acetylene process was about ¼ in. in thickness and, in turning, the chips came away long and curling, showing that the built up metal was tough and fibrous.

Excitation Systems for Turbo-Generators

VARIOUS SCHEMES IN USE. TYPES OF DRIVES, VOLTAGES AND METHODS OF CONTROL

IN CONSIDERING the reliability of a modern generating system one of the most vital factors deserving attention is the excitation system. Its rank of importance, however, compared to other component parts cannot be argued, because successful operation of a generator unit depends upon the proper functioning of all component parts. Yet, it is a fact that if the excitation system fails, the generator immediately loses its load.

There are a number of schemes in general use; one common practice has been to supply excitation to the fields of all generators from a common exciter bus, the latter in turn served by several separately driven exciters operating in parallel. This has been called the central system with separately driven exciters.

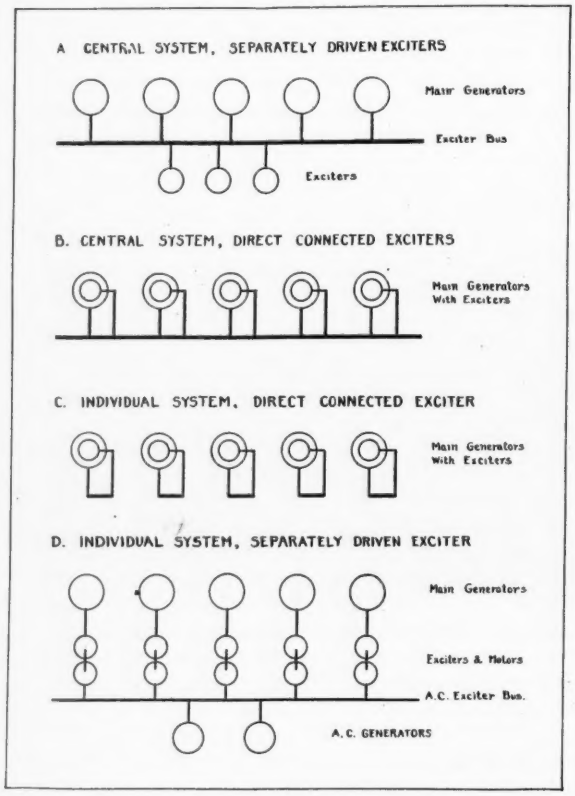


DIAGRAM SHOWING VARIOUS EXCITATION SYSTEMS

Another method of supplying excitation, which, as may be noted from the tabulation on page 55 is growing in popularity, and avoids some of the undesirable features of the common bus scheme, is the individual exciter system. In this, individual exciters are devoted solely to serving their respective main generators. By this individual arrangement, simplification in many ways is easily attained. System disturbances, moreover, are limited to a single generator unit instead of endangering the operating of the entire plant. This is known as the individual system with direct connected exciters.

A combination method in which both of these systems are combined is the central system with direct connected exciters, illustrated at B in the accompanying figure. In this case, the actual exciter arrangement is the same as in the individual system, but the exciters are all connected to a common bus from which all generators are supplied.

A fourth system, the individual system with separately driven exciters, is shown in D. Here each main generator is provided with its individual separately driven exciter set, all of which are supplied from a common a. c. exciter motor bus.

Which of these systems to install in a particular station depends largely upon individual conditions. The two systems most largely used are perhaps the central system with separately driven exciters, and the individual exciter system. Each, of course, has its own particular advantages but direct connection of the exciters to the main generator shafts seems an excellently simple solution to the exciter problem. Attention of the turbine room operator to an additional machine is not required and the exciter benefits by the good speed regulation of the most accurately governed prime mover in the plant, the main unit. The question of reliability of the prime mover driving the exciter is automatically eliminated, since shutting down the main turbine simultaneously removes the need for excitation of that unit. This is the system most used in large central stations.

While modern direct connected exciters are designed very liberally, both mechanically and electrically and even though the chance for trouble with these units may be so minimized that sole dependence upon it is no more hazardous than a dozen other vital accessories to the main unit, it is desirable, nevertheless, to have an emergency excitation bus with a reserve exciter driven by a steam turbine, water wheel or motor, so that the field of any generator may be thrown on this bus in case of trouble with one of the individual exciters. In cases where the common exciter bus is used a storage battery is often floated across this bus, but this cannot always be considered as taking the place of spare capacity. Its function is immediately and automatically to take over the load of an exciter which trips by relay action or ceases to generate, and carry that load until the exciter is restored to service or a spare put in its place. Its use does away with the necessity of keeping spare exciters on the bus and thereby permits more efficient operation. A battery is justified only if the cost of operating spare exciters on the bus, or if the value of increased assurance of continuous service during times when no spare exciters are available is greater than the fixed and operating costs of the battery. Most of the larger central stations in the cities consider the installation of storage batteries for this and other service essential.

Exciter voltages during the past few years have increased from 125 volts, which was standard for years (and still is for small plants) to 250 v. This voltage, as can be seen from the tabulation, is used in nearly all of the stations under consideration. Two hundred and

fifty volts is preferable from the standpoint of reduced costs and size of apparatus and cables. Where the station lighting is at 250 volts a. c. the exciter bus can be used for emergency lighting service if it is at 250 v. It has been suggested that even higher voltages than 250 v. can be used for large stations but no applications of such higher voltages have been made so far.

While the choice of exciter voltage is a matter of no great importance there are some cases where it is more desirable to use one voltage than another. A given machine requires a certain kilowatt excitation regardless of the voltage, so that with the higher of the two standard voltages (125 and 250) a lower current is required consequently a smaller size of conductor must be used for the field coils. In machines of small capacity this may result in a wire of such small cross-section, and a coil of such a large number of turns that a large amount of coil space is taken up by insulation. Trouble may also be experienced in high-speed machines, in supporting the coil properly against centrifugal force. In such cases 250 v may be a real handicap. Small turbo-generators on which it is desired to use copper strap bent on edge for the field coils, also have a lower limit for 250 v. excitation on account of the difficulty experienced in bending the straps to the proper shape. In extremely large turbo-generators a limit is reached in the other direction. That is, if 125 v. excitation is used the current becomes so large that difficulties in current collection are encountered. This accounts for the almost exclusive use of 250 v. in the stations listed in this survey, since it is in these stations that the larger generators are installed.

In cases where the alternators are excited from a common exciter bus, the question of exciter voltage range does not enter, since in such cases the exciters are required to operate at one voltage only. This condition also permits the exciters to operate well above the bend in the saturation curve so that good stability is obtained.

When the alternator excitation is controlled by varying the voltage of the exciter, however, the factors of voltage range and stability require consideration. In alternators of modern design the range of exciting current required at unity power factor is approximately 1½ to 1, and about 2 to 1 at .8 power factor. This means a range in exciting voltage of about 2½ to 1 at .8 power factor, and in more exceptional cases, the range in exciting voltage may reach 3 to 1. As pointed out by C. A. Boddie and F. L. Moon in a paper presented before the A.I.E.E. some years ago, an even greater range of exciter voltage than those here listed may be required by generators or synchronous condensers which have to supply charging currents to transmission lines at light load. Here a range in exciting voltage down to the residual voltage of the generator may be required.

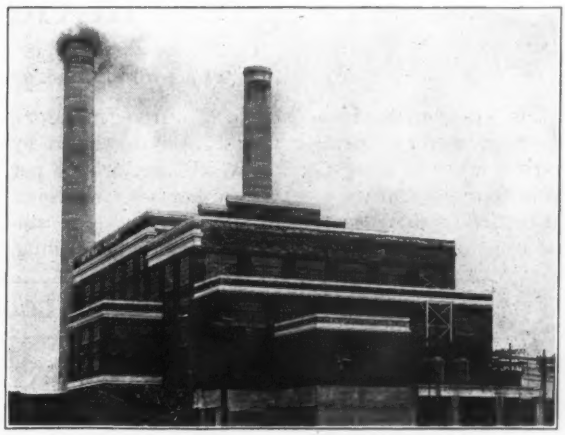
Method of Driving Exciters

Methods of drive have already been touched upon in our general discussion of exciter arrangement, in fact the type drive is largely dependent upon the type of system used. In the case of common excitation plants, a number of arrangements for driving the generators are in common use. Unless there are reasons, such as speed considerations, for instance, which prevent its use, the direct connection of the exciter to the main generator shaft is undoubtedly the most reliable and efficient. In small industrial plants where engines are used, belt-driven exciters are used to good advantage.

In relatively large plants, perhaps the most common method used is to drive some of the exciters by motors through transformers from the main a.c. bus and some of them by steam turbines. In this case, even if trouble occurs on the main a.c. system, excitation will not necessarily be lost, since it can be supplied by the steam-driven units.

Where house turbines are used to supply the auxiliary electric energy, the steam driven units can be omitted and only motor-driven units provided. For motor-driven units, the induction motor is the most satisfactory and is to be preferred in almost every case. This type of motor is unusually rugged and is not affected materially by ordinary voltage disturbances on the main a.c. system.

Synchronous motors have been used to drive exciters but their use, in most cases, introduces a certain amount of hazard, as regards reliability. These motors are more likely to fall out of step, and having direct current fields, require one additional operation on the part of the operator when starting. It has an advantage, however, in not being affected by voltage fluctuations, and in cases where the normal voltage fluctuates as much as 25 per cent it may be desirable to install the synchronous motor. In central station practice, however, such voltage fluctuations are almost unknown and in none of the stations listed on page 55 are synchronous motor-driven exciters used.



SUSQUEHANNA STATION

The dual type of drive, such as installed in the Susquehanna station may be used to good advantage since it renders the exciter system insensible to disturbances on the a.c. system. This system functions practically automatically without the installation of any automatic equipment not ordinarily used. If the exciters are being driven by the motors, loss of voltage with resultant reduction in speed permits the prime mover governors to function and transfers the drive to the prime mover. When voltage is restored to the motors the increased speed automatically cuts out the prime mover.

Control of excitation depends upon a number of factors which in turn are dependent upon the conditions existing at any particular plant. Where the common exciter bus is used, rheostats must be provided for both the exciter field and the main generator field. The rheostat in the exciter field is usually small in range and is used to maintain a predetermined and constant exciter bus voltage for good parallel operation of the exciters. The rheostat in the main generator field, on the other hand, must have a wide range of small steps, since it is used for controlling the voltage regulation of the main unit. Sometimes, the exciter field rheostat is adjusted to assist the main field rheostat in meeting the excitation requirements of a heavy load but as a rule such demands can be met by manipulation of the main field rheostat alone. In stations where the individual exciter scheme is employed, the excitation is controlled by means of the exciter field rheostat alone. As has been mentioned previously under "Voltage of Exciters" in such cases the exciter field should be designed liberally and the exciter rheostat made capable of adjusting the exciter terminal voltage throughout a wide range in order to meet conditions such as dropping of exciter voltage due to abnormal slowing down of the main unit. With exciter field control a comparatively small rheostat performs the duty which would otherwise be required of a large and inefficient main rheostat.

It is common practice, however, particularly in cases where standby excitation from a common bus is provided to also install a main field rheostat for each unit, which normally is inoperative. Only in emergency when normal excitation is shut off and excitation taken from the standby source, is this main field rheostat brought into action.

In large central stations where load fluctuations occur at a comparatively slow rate, these rheostats are regulated in a satisfactory manner by hand by the station operators. Where the load on the system fluctuates rapidly, however, automatic operation of the main field rheostat is desirable and in modern stations such automatic control is usually provided as described under Voltage Control in the preceding article.

Progress in Generator Cooling

The Closed System of Cooling Used at Present May Lead to the Use of an Inert Gas for Cooling

DUE TO increase in capacities of turbo-generators, the problem of dissipating the heat developed by electrical losses in the generator, which vary from 3 per cent to 8 per cent of the total power, has become serious.

Practically all recently-installed, large power stations are using the closed system of generator cooling, with air as the direct cooling medium and water as the source of cooling; but developments are leading toward the adoption of an inert gas in preference to air. By this means, danger of fire is avoided because combustion would not be supported by the cooling medium.

Coolers of the surface type are mostly used, al-

GENERATOR COOLING DATA

PLANT	SYSTEM	COOLING AIR		COOLER		TEMP. DEG. F.				HEAT	FIRE PROTECTION
						AIR		WATER			
		SOURCE OF COOLING	VOL. CU. FT. PER. MIN.	TYPE	SURFACE SQR. FT.	IN	OUT	IN	OUT	RECLAIMED	
COLUMBIA	CLOSED	CONDENSATE & DEEP WELL		SURFACE				55 90	98		
CRAWFORD	CLOSED			FIN TUBES & TUB. SURFACE						NO	
PHILO	CLOSED	CONDENSATE & GROUND WATER	90 000	FIN SURFACE							
TRENTON CHANNEL	CLOSED	RIVER WATER		FIN TUBE SURFACE			104	85			
RICHMOND	CLOSED	CONDENSATE	110 000		2-19700 EACH COOLER						
KEARNY	CLOSED	SALT WATER	90 000	U FIN SURFACE	1-18240 1-22800			85			
AVON	CLOSED	CONDENSATE		FIN SURFACE	15000		85				HIGH PRESSURE STEAM JETS IN END BELLS OF THE GENERATORS
SOMERSET	CLOSED	RIVER WATER		FIN SURFACE	12720	122	82	66	88	NO	
NARRAGANSETT	CLOSED	SALT WATER	100 000	FIN SURFACE				90		1150 SQR. FT. HEAT EXCHANGER	PERFORATED SPRAY PIPES IN GENERATOR END BELLS ADMIT AIR OR STEAM TO WINDINGS
EDGAR	CLOSED	CONDENSATE & SALT WATER	90 000	AXIAL SURFACE	17680						CLOSED SYSTEM - CO_2 GAS
LONG BEACH	CLOSED	OCEAN WATER		FIN SURFACE							
SEAL BEACH	CLOSED	CONDENSATE & CIR. WATER			26300		97			AIR PREHEATERS RECLAIM HEAT FROM FLUE GASES	
SUSQUEHANNA		RIVER WATER									
CAHOKIA	CLOSED		80 000 & 84 000	SURFACE		140	100	80	85	CONDENSATE CIRCULATED THROUGH COOLER	CO_2
RIVERSIDE	CLOSED		65000								
WAUKEGAN		WASHED AIR	75000								
VALMONT	CLOSED	LAKE WATER WASHED AIR									
HALESBAR	CLOSED			SURFACE							
BIG SIOUX	CLOSED	CONDENSATE & CIR. WATER		U FIN SURFACE	5750	135	95				
NEOSHO	COOLING TOWER	COOLING TOWER	50000							YES	
DRESSER	CLOSED	RIVER WATER		RADIATOR SPRAY							
EDGEWATER	CLOSED			SPRAY							STEAM JET
BARBADOES	CLOSED		75000	SPRAY							
PINE GROVE	CLOSED	SPRAY POND	35000	SPRAY	35000						
BETTENDORF	CLOSED										

though some recent installations have given preference to the spray type of cooler. The surface-type coolers are usually fitted with radiating fins which, in a few cases, as shown in the table, are of tubular construction.

Cooling air should be clean as well as cool, since dirt eventually clogs up air passages, causing overheating of coils. Air filters have, therefore, been employed for this purpose but the tendency appears to be toward larger use of spray washers in a number of recent power plant installations. It has been found that spray washers are more satisfactory in removing dirt and heat than cloth filters.

For the most part, condensate is used for cooling the air but, where raw water is available from lake or river sources, it is employed for this purpose. In many instances, where no large fresh water supply is available, as when the plant is located adjacent to the sea, power plant operators are using salt water, at least as make-up water, in the cooling system. Under these conditions, the practice is to use condensate as the principal cooling source and recirculate it, adding salt water as required.

Practice indicates temperatures of outgoing air of from 90 to 100 deg. F., the drop in temperature due to the cooling process being about 40 deg. F. The quantity and temperature range of the cooling water varies according to the available temperature of the intake water.

Some operators pipe the discharged hot air from the turbo-generator to the suction of the draft fans, thus utilizing the waste heat but the value of this heat is not as great as may be expected, amounting to only about 5 per cent. With the employment of air preheaters, which are rapidly coming into use, this saving practically disappears.

Fire Protection

Use of increasingly large capacity turbo-generators has led to greater danger of fire. The only inflammable part of a modern generator is the insulation but, in case of fire due to electrical losses, this insulation is rapidly consumed. Observation of such conditions indicates that, within a few seconds after starting, the flames have swept entirely around the circumference of the generator and, within one minute after such fires have started, the iron shields covering the projections of the armature windings become white hot.

It is evident, therefore, that precautions should be taken to prevent the starting of flame rather than for putting it out after it has started. Development toward this end leads first, toward the perfection of insulating materials, with perhaps the development of an incombustible insulation, and the use of inert gases such as carbon dioxide, carbon tetrachloride and hydrogen as cooling mediums. Several installations have either already adopted CO_2 for cooling as well as fire prevention or have provided for its later use. So far as is known, hydrogen has not yet been commercially employed for this purpose.

Carbon dioxide in liquid form has recently been employed as the extinguishing medium. The advantage claimed over gaseous carbon dioxide is that the former avoids the objectionable possibility of freezing. It is a nonconductor of electricity, nonpoisonous and noninjurious substance and creates no objectionable residue that must necessarily be cleaned up.

Fire Detection Methods

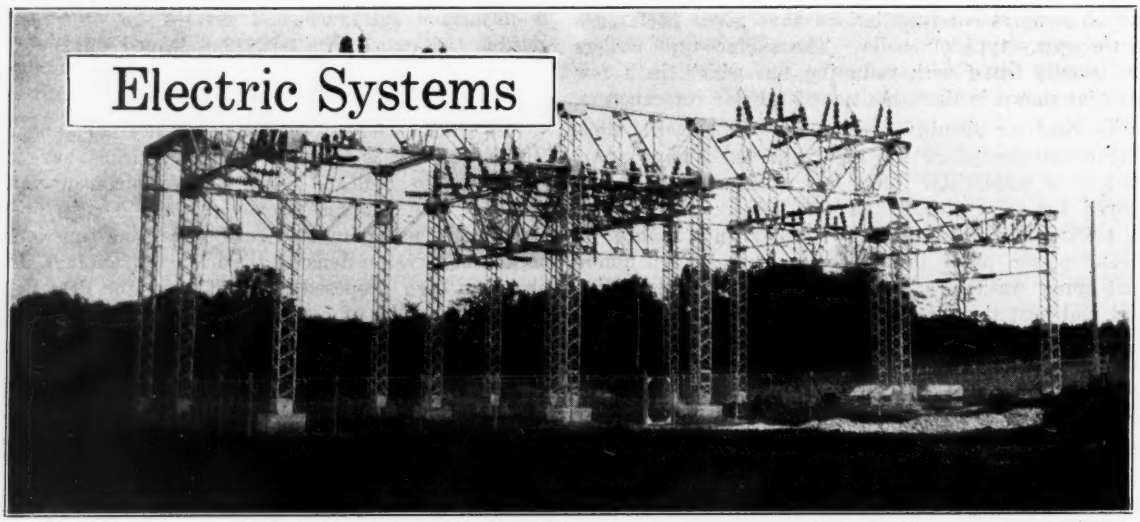
In order to have some way of indicating danger by fire before it has actually occurred, means have been developed to indicate rising temperatures in various parts of the winding. Some of these devices operate electrically, using inserted fuse wires; one functions by means of a vapor tension thermometer, another device that has been proposed is based upon the detection of smoke by means of a photo-electric cell.

In closed systems, which are now generally used, fire could be checked when the oxygen contained in the closed ventilating system is consumed as combustion would no longer be supported but, by this time, considerable damage would have resulted. Such method cannot, therefore, be properly classed as fire prevention.

BROTHERHOOD OF LOCOMOTIVE ENGINEERS BUILDING

Sprinkler heads which are located in different parts of the winding are used. This device acts as a means of detection of temperature rise as well as of extinguishment. Fire baffles are also used to direct the air currents radially through the generator winding in order to suppress the circumferential component of the movement and hence the spread of destruction.

Steam is used in some plants, as indicated in the table, for fire checking purposes. The same objection raised regarding sole dependence upon the closed principle for checking fires as stated in the preceding paragraph applies here with the added objection of greater resultant mess. Success in fire prevention seems to lead, on the whole, toward the use of inert gas.



Features of the Generator Connection

THERE IS A GROWING TENDENCY TO CONNECT THE GENERATOR DIRECTLY TO THE PRIMARY OF STEP-UP TRANSFORMERS

WHILE THE PRACTICE of connecting the main generators directly to a main station bus through oil circuit breakers is still quite general, there seems to be a growing tendency to avoid the use of a low tension main bus and to connect the generators directly to the primary windings of step up transformers. This latter arrangement eliminates the complexity of the low tension bus structure and, particularly in stations where practically the entire output is to be transmitted to distant points at high voltage seems to be highly satisfactory from both an operating and initial standpoint.

Where a large number of high capacity feeders leave the station, however, at various voltages, this scheme cannot be adopted and a low voltage bus must be installed and, as can be seen from the accompanying table, this arrangement is used in most of the stations listed. The actual wiring arrangement, however, differs in each station.

At Crawford Avenue, for instance, the current from the main generator passes through reactors in each lead, through oil circuit breakers to either or both of two main buses. The oil circuit breakers used are the General Electric, hydraulically operated type having ratings of 4000 amp. As in all of the other stations listed, control of the switches is effected from the main operating gallery. The two sections of the main bus are normally operated in parallel, but in the event of trouble on either section of the system, the two sections are automatically cut apart, thus isolating the defective section.

The arrangement at Philo is entirely different. Here, as at the Twin Branch station, there is no high-tension bus system in the station itself. Current generated at 11,000 v. passes directly to the outside of the station to transformers, which raise the voltage to 132,000 v. and the power then goes to the high tension switching station. Control of the 132,000 v. switches is from the main control room in the station. There is no paralleling of machines on the 11,000 v. side except for synchronizing.

At Trenton Channel a similar arrangement exists. Current produced at 12,000 v. goes direct to step up transformers, where the potential is raised to 132,000 v. The secondaries of these transformers are connected through oil circuit breakers to duplicate 132,000 v. busses.

At Richmond main busses are provided in the station. Main generator leads connect to 5 per cent reactors and then through oil circuit breakers to duplicate 13,200-v. busses.

An interesting electrical system is that installed at Kearny. Here, segregation of equipment has been developed to a high degree. Normally, the generators feed directly to their respective transformer banks and operate in synchronism through the group-tie and main tie busses, both of which are installed in duplicate. Any generator can, however, be connected to any bank of transformers by means of the transfer bus. The operation of groups of three and two units respectively, as separate stations and, if need be, at different voltages, is permitted by sectionalizing oil circuit breakers in the group-tie bus. This breaker is normally open and the two sections of the bus tied together by means of the main tie bus, thereby adding a reactance of 4 per cent at 2000 amp. in each connection to 7 per cent at 1200 amp., provided between each generator bus and the group tie-bus.

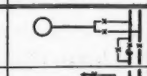
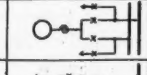
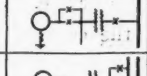
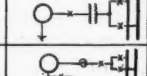
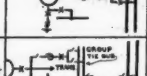
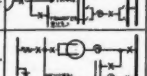
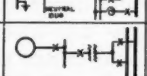
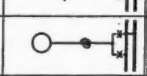
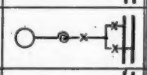
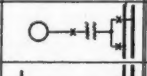
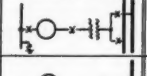
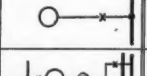
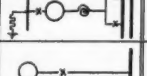
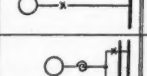
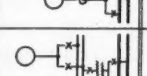
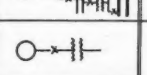
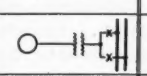
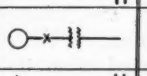
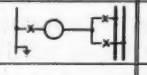
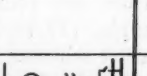
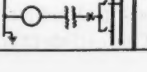
Avon station, as indicated in the table, has an arrangement in which the current passes from the generator through reactors, and oil circuit breakers to the main bus. Synchronizing is done on a separate synchronizing bus, as shown in the diagram.

At both the Long Beach and Seal Beach stations in California, the generator leads connect direct to step up transformers, which in turn feed into duplicate high tension busses.

Susquehanna, Cahokia, Waukegan and Dresser stations all have main busses at generator voltage, while at Hales Bar, Big Sioux, Neosho and Pine Grove the

generators connect directly to step up transformers. At Valmont the generators connect through oil circuit breakers to a 13,000-v. synchronizing bus, from which the current goes to step up transformers and oil circuit breakers to a 90,000-v. bus. At Pine Grove there are no low-tension breakers between the generators and

GENERATOR CONNECTION

PLANT	METHOD OF CONNECTION	SINGLE LINE DIAGRAM	SWITCHING SYSTEM		PROTECTION			
			TYPE & VOLTAGE OF SWITCHES	METHOD OF CONTROL	REACTORS	RELAYS	GROUND	BUSS ARRANGEMENT
COLUMBIA	GENERATOR TO OIL C.B. TO BUS		UNIT CELL TYPE. SOLENOID OPERATED 15,200 V.	REMOTE FROM CONTROL ROOM	IN BUSES ONLY	DIFF. RELAYS ON MAIN GENERATORS		ISOLATED PHASE
CRAWFORD	GENERATOR TO EITHER OF 2 OIL C.B'S. TO 2 MAIN BUSSES		HYDRAULICALLY OPERATED OIL C. B's.	OIL PRES. REMOTE ELECTRICAL	IN EACH GEN. LEAD	BAL. RELAYS ON GEN. NEUTRALS. RELAYS ALSO ISOLATE FAULTY BUS IN CASE OF SHORT	GEN. CONNECTED TO NEUTRAL BUS GROUNDED THRU 3 OHM RESISTOR	HOR. ISOLATED PHASE
PHILO	GENERATOR THROUGH OIL C.B. TO TRANSFORMERS TO 132 KV. BUS. NO PARALLELING ON 11,000 V. SIDE		11 & 132-KV. OIL C.B.	REMOTE	NONE	MULTI-CONTACT PQ-6 DIFF. RELAYS IN GEN. LEAD & NEUTRAL	NEUTRAL GRD. 2-OHM RES. AUTO. SHUNT. THERMAL R	OUTDOOR 132-KV.
TRENTON CHANNEL	GENERATOR TO L.V. OIL C.B. TO TRANSFORMERS TO 132 KV. OIL C.B. TO DUPLICATE H.T. BUS		25-KV. OIL C.B. ON GEN. 132-KV. OIL C.B. ON H.T. SIDE	ELECTRICAL REMOTE CONTROL	NONE	DIFF. RELAYS ON GEN. LEADS	GEN. NEUTRAL SOLIDLY GRD.	OUTDOOR H.T.
RICHMOND	GENERATOR TO REACTOR TO OIL C.B. TO DUPLICATE 13,200 VOLT BUS		25-KV. OIL C.B. DEAD POT, GRAVITY OPEN DESIGN.	REMOTE CONTROL	5% IN EACH LEAD	DIFF. PROTECTION. TYPE CZ RELAYS DISCONNECT GEN. FROM BUS. THIS DOES NOT OPEN FIELDS.	GEN. NEUT TO EITHER TEST BUS OR GRD THRU 4 OHM RESISTOR	VERTICAL ISOLATED PHASE SYSTEM
KEARNY	GENERATOR TO OIL C.B. TO TRANSFORMERS. ALSO TO TRANSFER & GROUP TIE BUS		HOT. OPERATED 25000 V. 3000 A. OIL C.B.	REMOTE STOR. BAT. SUPPLY	5% IN EACH LEAD	DIFF. RELAYS. INTERWINDING PROTECTION BY CUR. TRANS WITH 2 PRIMARIES. S.C. RELAY	NEUTRAL GRD. THRU 2-4 OR 8 OHMS. OIL C.B. ACROSS RES.	VERTICAL ISOLATED PHASE
AVON	GENERATOR TO REACTOR TO OIL C.B. TO MAIN BUS. THEN TO TRANSFORMERS OR SYN. BUS.		MOTOR OPERATED 15,000-V	REMOTE	5% IN GEN. & BUS TIES	DIFF. RELAYS PROTECT AGAINST INTERNAL TROUBLE. GEN. HAS 2 CCTS. PER PHASE	GEN. GRD. THRU. OIL C.B. TO GRD. BUS. 3 OHM RES. IN GRD.	VERTICAL ISOLATED PHASE
SOMERSET	GENERATOR TO OIL C.B. TO INDIVIDUAL BUS. THIS CONNECTS TO TRANSFORMERS		HOT. OPERATED 15-KV. LOW T. 66-KV. HIGH T.	REMOTE	NONE	BAL. RELAYS AUTO. DISCONNECT GEN. IN CASE OF TROUBLE		2 H.T. OUTDOOR BUSES SECTIONALIZED AT CENTER
NARRAGANSETT	GENERATOR TO REACTOR TO OIL C.B		1,500,000 KV.A. INT. CAPACITY	REMOTE	YES			VERTICAL ISOLATED PHASE
EDGAR	GENERATOR TO REACTOR TO OIL C.B. TO BUS		15-KV. OIL CIR. BREAKERS	REMOTE	YES	DIFF. RELAYS TRIP GEN. OIL C.B. FIELD C.B. & TUR. THROTTLE. REV. CUR. RELAYS ON ALARMS.	NEUTRAL GRD. THRU. OIL C.B. & 4 OHM RES.	ISOLATED PHASE, VERTICAL
LONG BEACH	GENERATOR TO TRANSFORMER TO OIL C.B. TO 2 MAIN 72 KV. BUSSES		72-KV. 3-POLE S.T. 11,000 V. SPS.T. FOR NEUT. GRD.	REMOTE		BAL. RELAYS OPEN MAIN BREAKERS. ALSO OPEN FIELD AFTER GEN. IS CUT OFF.	NEUTRAL GRD. THRU. OIL C.B.	DUPLICATE 72,000 V. BUSES.
SEAL BEACH	GENERATOR TO TRANSFORMER TO OIL C.B. TO EITHER OF 2 110 KV. MAIN BUSSES		110,000-V. OIL C.B.	REMOTE	NONE	DIFF. PROTECTION ON ALL MACHINES.	NEUTRAL TO OIL C.B. TO GRD. BUS. 7.6 OHMS.	110 KV. BUS INSIDE. DUE TO SALT AIR
SUSQUEHANNA	GENERATOR TO MAIN BUS TO OIL CIRCUIT BREAKER		S.P. SOLENOID OP. TRUCK TYPE 15-KV.	REMOTE	NONE AT PRESENT			GROUP PHASE
CAHOKIA	GENERATOR TO REACTOR TO OIL C.B. TO MAIN BUSSES		MOTOR OPERATED S.P. 13-KV.	REMOTE	3% IN EACH LEAD	DIFF. RELAY PROTECTION.	NEUTRAL GRD. THRU. 6 OHM RES.	VERTICAL ISOLATED PHASE
RIVERSIDE	GENERATOR TO OIL C.B. TO MAIN BUS		13-KV. OIL C.B. CELL CONST.	REMOTE				DOUBLE BUS
WAUKEGAN	GENERATOR TO REACTOR TO OIL C.B. TO MAIN DOUBLE 12 KV. BUS		12 KV. OIL C.B. MOT. OP. AIR BK SW. ON 132 KV.	REMOTE	IN EACH LEAD	BAL. RELAYS OPEN BREAKER ON INTERNAL TROUBLE	THRU NEUTRAL BUS SOLIDLY GROUNDED	GROUP PHASE ARRANGEMENT
VALMONT	GENERATOR TO OIL C.B TO 13 KV. SYNCHRONIZING BUS. THEN THRU OIL C.B. TO TRANS. TO 90 KV. BUS		3 POLE, 15 KV. SOLENOID OP.	REMOTE	NONE AT PRESENT BUT SPACE PROVIDED		NEUTRAL NOT GROUNDED	GROUP PHASE
HALES BAR	GENERATOR TO OIL C.B. TO TRANS.		OIL C.B.	REMOTE				
SIOUX CITY	FROM GENERATOR TO TRANS. TO OIL C.B. TO EITHER OR BOTH OF TWO 33,000 V. BUSES		OIL C.B.	FROM CONTROL ROOM	REACTORS IN FEEDERS		TRANS. ΔY CON NEUT. OF SEC. Y GRD. THRU O.C.B	OUTDOOR BUS
NEOSHO	FROM GENERATOR TO OIL C.B. TO PRIMARIES OF 12,000/60,000/132,000 V. TRANS		12-KV. OIL C.B.	REMOTE				60-KV. BUSES ARRANGED IN OUTDOOR SUB.
DRESSER	GENERATOR TO OIL C.B. TO EITHER OR BOTH OF TWO MAIN 13 KV. BUSES		13000 V. 3-P. S.T OIL CIRCUIT BKRS. MOTOR OPERATED	REMOTE	NONE AT PRES. BUT CAN BE ADDED	DIFFERENTIAL RELAYS OPEN MAIN BREAKERS WITH INTERNAL TROUBLE	GEN. NEUTRAL TO GRD. BUS. GRD. MADE THRU RES.	GROUP PHASE
EDGEWATER			OIL CIRCUIT BREAKERS 440 V. 6600 V. 22,000 V.	REMOTE				6600 V. INDOOR GROUP. 22 KV. INDOOR IN GAL.
BARBADOES			13,200 V. OIL C.B SOLENOID OPERATED	REMOTE				
PINE GROVE	NO L.T. BREAKERS BETWEEN GEN. AND OUTDOOR TRANS. SYNCHRONIZING DONE ON H.T. SIDE.		3 P. S.T. GANG OPERATED. OIL C.B. 12-KV.	REMOTE	NONE	DIFF. RELAYS ACROSS GEN. OPEN BKRS. OVERLOAD RELAYS GIVE ALARM BUT DO NOT OPEN CCT.	GEN. SOLIDLY GROUNDED THRU NEUTRAL BUS	66-KV. DOUBLE BUS.

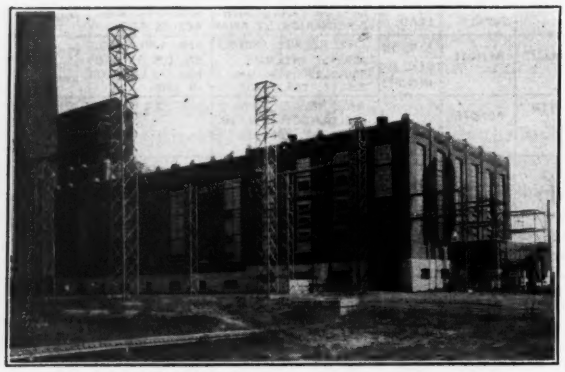
outdoor transformers, all synchronizing being done on the high-tension side.

Switching

High voltage switching in all large stations today is accomplished by means of oil circuit breakers. The type of switch used varies considerably, however, each station apparently selecting a switch which seems best suited to their particular requirements. All switches used are automatic in operation and are remote controlled from the main control room.

Most oil circuit breakers are electrically operated, either by motor through suitable bearing and linkage or by use of the solenoid. The solenoid-operated breaker on large switches is likely to require large currents for its operation but, otherwise, one type operates as satisfactorily as the other.

During recent years the hydraulically-operated type of switch has been developed. This switch, which is used at Crawford Avenue, is also equipped with disconnecting switches which may be operated automatically



NEOSHO PLANT OF THE KANSAS GAS & ELECTRIC CO.

by the switch mechanism or operated manually from the mechanism floor. The mechanism is spring operated, the spring being compressed by oil under a pressure of about 450 lb. per sq. in. furnished by gear pumps.

In operating this type of circuit breaker, the charging switch button is first pulled. This starts the hydraulic pump and opens a solenoid-operated valve on the mechanism and, when the spring is fully compressed the pump is shut down by a pressure governor. A signal lamp on the control board then lights, notifying the operator that the closing button may be pulled. The operation of the closing button releases the spring permitting the stored energy in it to close or open the switch.

Because of the high voltages employed and the tremendous amounts of energy stored in the system, it has become almost universal practice to install the oil switches in cells or compartments, separating each phase. The switches themselves are made with external contact arrangements which permit their easy removal or placement in the cells. In a number of installations the compartment doors are so interlocked with the disconnecting switch mechanism that they cannot be opened or removed when the oil switch is alive.

In order to protect the generator from damage due to external disturbances or to protect the system from serious disturbance due to failure of one generator, it has become the practice to provide means whereby, in case of trouble, the generator is automatically disconnected from the system, or whereby the current interchange between the machine and the system is limited to a safe maximum value. According to present-day practice apparatus is only provided to disconnect the generator in case of internal failure. Relays are not usually provided to open the breakers in case of overcurrent or excessive temperature. It is important, however, to keep the operators informed as to the overcurrent and temperature conditions of the machines but this is usually done by providing an audible or visible signaling device.

In the case of the generator, two kinds of failure are, as a rule, considered: first, loss of field or failure of the field winding and, second, failure in the armature or station windings. In large machines protection of the field is hardly justified because with the low voltages employed on the field failure rarely occurs. Furthermore, schemes for the protection of the field are somewhat complicated.

Protection against failure in the armature is exceedingly important, however, and as may be noted from the accompanying tabulation nearly all stations have some means provided for doing this. Failures of this type can be classified under four general headings. (1) Phase to phase short circuits. (2) Short-circuited turns. (3) Open circuits. (4) Grounds.

Since faults in generators usually start as grounds from phase windings to the frame, it is highly desirable to disconnect the generator from the line, the instant the ground occurs, that is, before a phase to phase short circuit can occur. This is accomplished by grounding the neutral and providing suitable relays, which will function when the ground occurs. If the neutral is not grounded a fault of this sort will not unbalance the phase current and it is difficult, therefore, to locate it until it has developed into a phase to phase short circuit.

At the present time there is no ideal or simple scheme for the protection against all classes of trouble until the fault has developed into an actual phase to phase short circuit, but by going to a more complicated scheme or by a combination of several schemes adequate protection is secured against each class of fault.

Several schemes for generator protection are available. These may be classified roughly into differential and directional schemes, according to the principle of operation. Differential schemes include all schemes in which currents, however large, flowing in their proper paths, are balanced against each other so as to have no effect on the protective relays, whereas any current diverted from its proper path as the result of an internal fault operates the relays. This principle of operation allows relatively sensitive settings, since normally no current flows in the relays; however, much may be passing through the machine.

There are four systems in use which involve this principle, (1) the simple differential scheme, (2) self-balanced schemes, (3) combination split conductor and differential scheme, and (4) the mid-point scheme.

The differential scheme is the most common form of

generator protection and is widely used. As can be seen from the table, practically all stations on which information was available employ some form of differential protection.

In applying the simple differential scheme of protection to generators both ends of each phase winding are brought out of the machine and current transformers installed on each end. A relay operates to close its contacts whenever the current becomes unbalanced in the two corresponding current transformers.

Transformer Developments

Prevailing Types, Connection and Tap Changing Arrangements Are Discussed and Oil Sludging and Transformer Cooling Developments Pointed Out

TRANSFORMER TYPES have not changed radically during the past 2 yr. The core type, because its construction offers a maximum resistance to mechanical distorting forces, is usually selected for the larger loads such as for distribution, while the shell type is usually used for power plant service work. Another reason for the selection of the core type for heavy service is that it can be more readily insulated for the highest voltages now in use.

Connection and Tap Changing Arrangements

The Delta-Y arrangement appears to be the most used on the main units. A new development in transformer operation is the adoption of tap changes or ratio adjusters. By the use of this device the transformer is better enabled to meet the needs of rapidly growing systems such as obtain in most present-day central stations. A tap changer has been developed which can be operated when the transformer is loaded and its ratio varied at will. No switching is done in the main transformer bank and no current is made or broken by the dial switches.

The control mechanism is so designed and interlocked that it will operate the breakers and move the dial switches in either direction in the proper sequence and will stop before moving a dial switch, if either of the breakers fails to operate when it should or if the last tap has been reached. The breakers are also interlocked mechanically, so that neither can open, if the other is open. Locating the taps in the middle of the windings instead of at the end permits not only of protecting the taps from line surges, to which the ends of the windings are frequently subjected, but also makes possible maintaining the winding in a balanced condition. Removal of taps from the end of the winding also simplifies the matter of insulating the end turns.

Difficulties Due to Oil Sludge

Oil sludge in open-type transformers has greatly increased in amount in recent years due to the higher operating temperatures, longer and heavier load periods and in some cases to overexcitation. The formation of oil sludge impedes cooling and tends to cause insulation breakdown. Where means are taken to prevent the oxidizing reaction of the oil by sealing against air contact or by the use of low operating temperatures and normal excitation, no appreciable amount of sludge will form. To overcome this trouble in the open type of transformer, operating under temperatures permissible under present standards or overexcited, the only way to avoid sludging appears to be the improvement of the quality of the oil or a change in the method of cooling the oil so as to lower the temperature.

Location outdoors of main transformer is increasingly popular in this country as will be seen by reference to the above table.

Cooling Methods

Insulating materials deteriorate and iron loses its strength when exposed to high temperatures for extended periods. With constant magnetic and current density, the rating of a transformer increases with the fourth power of the linear dimensions; the weight and losses with the third power; and the radiating surface with the second power. It will be seen, therefore, that a limit is soon reached beyond which natural ventilation is inadequate. Forced ventilation by air blast may then suffice but oil immersion is more effective and serves to insulate as well as cool the transformer.

TRANSFORMER DATA

PLANT	TYPE	CONNECTIONS	POTENTIAL CHANGE	LOCATION	COOLING SYSTEM	SWITCHING
COLUMBIA		Δ — Δ Δ — Y	33000 to 66000	OUTDOORS ADJ POWER PLANT	OUTSIDE SELF COOLED	
CRAWFORD	CORE		4000 to 2300	OUTDOORS		RECEIVE 12000 V. STEP UP TO 33000 V OVER 3 CONDUCTORS UNDERGROUND LINES
PHILO	CORE	Δ — Y	2300 to 440	OUTDOORS ADJ POWER PLANT	WATER	MASTER PUSH BUTTON IN CONTROL HOUSE STARTS 440 VOLT MOTORS SINGLY AND IN PROPER ORDER TO REDUCE STARTING LOAD
TRENTON CHANNEL	CORE	Δ — Y Δ — ☆	13200 to 132000	OUTDOORS	WATER	
RICHMOND				OUTDOORS IN CT UNIT 2 BLDGS	WATER	CONTROL SWITCH IN OPERATING ROOM SIMULTANEOUSLY STARTS SEPARATE MECHANISM ON EACH OF THREE TRANSFORMERS
KEARNY				OUTDOORS		
AVON	CORE	Δ — Y	2300 to 2300		SELF COOLED AND WATER	
SOMERSET				OUTDOORS		CONVENTIONAL
NARRAGANSETT	CORE			OUTDOORS		
EDGAR						
LONG BEACH				OUTDOORS DET. 2 BLDGS.	OIL	
SEAL BEACH			2300 to 66000 TO 110 000		WATER TO WATER SEA WATER AT TANKS	
SUSQUEHANNA	CORE			INTERIOR OF PLANT AND BLDG.		HIGH VOLTAGE TRUNK TYPE
GANOKIA	CORE	Δ ZIG ZAG				
RIVERSIDE	CORE	Δ — Y	33000 to 6600	OUTDOORS	WATER	
WAUKEGAN	CORE	Y	13800 to 33000	OUTDOORS	WATER	
VALMONT		☆		OUTDOORS		
HALESBAR	CORE	Δ — ☆	13200 to 132000		WATER	
BIG SIOUX			6600 to 33000			
NEOSHO	CORE					
DRESSER	CORE			OUTDOORS	SELF COOLED DRY TYPE	
EDGEWATER	CORE	Δ — Δ Δ — Y	24000 to 33000		WATER	
BARBADOES		OPEN Δ		OUTDOORS ADJ SERVICE BLDG	AIR	
PINE GROVE						
BETTENDORF	CORE			IN ENG. ROOM		

Corrugated steel tanks are universally used for self-cooled transformers of moderate sizes, while larger units use steel plate tanks with external fins, tubes or specially-designed radiators.

Water-cooled transformers are cheaper than self-cooled units but require considerably more equipment in the nature of piping; moreover the cost of the water for cooling adds to its initial, as well as operating, expense. If a large supply of water is not available for this purpose, methods of cooling such as cooling ponds or towers must be provided.

Most of the plants investigated, as indicated in the table above, use the water-cooled transformers.

As the cost, of air-blast transformers including installation, is usually greater than for self-controlled, their use is practically confined to localities where the presence of a large quantity of oil is objectionable.

Where oil is used in transformers care must be taken to keep it dry, since the smallest trace of moisture tends to destroy the insulating value. Thermal and chemical drying processes are used for this purpose. Special multiple filters with absorbent screens give satisfactory results.

Arrangement of Busses

Use of Isolated Phase System, Interlocks and High Voltage Switching Are Principal Features

ARRANGEMENT OF BUSSES in the electrical system of the modern power plant must, of course, be worked out to suit the requirements of each plant but the significant development of the past few years seems to be the employment of the isolated phase system for indoor work and the use of the outdoor substation, which will be treated elsewhere.

Of the plants listed on the accompanying table it will be noted that such plants as Columbia, Crawford, Richmond, Kearny, Avon, Narragansett and Cahokia use this system, modified, of course, to suit their individual needs. In some cases, as at Columbia, the system is of the double bus type equipped for dual switching.

Some of the stations, like Philo, do practically all of the switching on the high-tension side of the transformers, the switching being done in the outdoor substation by remote control from the board in the plant. Long Beach has a duplicate sectionalized bus system at 72 kv., on which all the switching is done at this voltage, while Seal Beach uses 110-kv. switching equipment on the high-tension side.

Of particular interest in the switching arrangements are the hydraulically-operated oil circuit breakers used at Crawford Avenue, Fig. 1, and breakers of high capacity used at some of the other stations. The 132-kv. breakers at Trenton Channel are rated at 1,500,000 kv-a. capacity and breakers for the new unit at Narragansett have the same rating. The circuit breakers at Cahokia on the generators and tie lines are motor-operated.

Another arrangement that has been coming into use is the placing of interlocks, often mechanical, on circuit breakers and disconnecting switches and on the compartment doors in switch houses to insure proper sequence of operation. These interlocks function in

BUS ARRANGEMENTS

PLANT	GENERAL TYPE	MAIN BUS VOLTAGE	EXCITER	INTERLOCKS	MAIN CIRCUIT BREAKERS	DISCONNECTS	SAFETY DEVICES	AUXILIARY BUS
COLUMBIA	VERT. ISOLATED PHASE DUAL SWITCHING	13,200		C.B. & DISCONNECTS COMPARTMENT DOOR	15.2 KW. RATED	15,000 VOLT REMOTE HAND OP.		
CRAWFORD	ISOLATED PHASE	DOUBLE 12000 V. BUS WITH FEEDERS	INDIVIDUAL DIRECT CONN. EXC. ON EACH UNIT		OIL C.B.'S HYDRAULIC OPERAT.			
PHILO	OUTDOOR REMOTE CONTROL	11,000 VOLT	INDIVIDUAL EXC. ON EACH UNIT		132,000 V			HOUSE SERVICE FROM TRANS. DIRECT CONN. TO GENERATOR LEADS
TRENTON CHANNEL	DOUBLE BUS SYSTEM	POWER FROM GEN. TO TRANSFORMERS TO 120,000 V. BUS			1,500,000 KV.A. 132,000 V.	EITHER SIDE OF C. BREAKER	DIFFERENTIAL RELAY TRANS.-SELECTIVE DIFF. RELAYS	MOSTLY D.C. AUX. FROM D.C. H.GEN. A.C. FOR P.C. EQUIP.
RICHMOND	VERTICAL ISOLATED PHASE	13,200	250 VOLT	C.B. & DISCONNECTS	13,200 V. 1,400,000 KV.A.	3 AND 6 POLE GANG OPERATED	SECTIONALIZING REACTORS-MAIN BUS	2-2,300 V. SECTIONALIZED
KEARNY	HORIZONTAL AND VERT. ISOLATED PHASE	13,800		OIL C.B. DISCONNECTS AND COMPARTMENT DOORS			DIRECT MECH. & ELEC INTERL'KS-SELECT. MECH. INTERLOCKS	2-23,000 V. 2-440 V.
AVON	VERT. ISOLATED PHASE	13,200						
SOMERSET		13,8000	SPARE EMERG. EXCITER EXCITER FOR EACH UNIT				STARTING POWER THROW OVER TO	FROM STA. SERV. BUS AUX. BUS
NARRAGANSETT	VERT. ISOLATED PHASE	11,000	INDIV. EXC.-EXCITATION FROM BUS TO ANY EXCITER					23,000V.
EDGAR	ISOLATED PHASE			C.B. & DISCONNECTS				
LONG BEACH	HIGH VOLTAGE SWITCHING	72 KV. DUPLICATE SECTIONALIZING	INDIV. EXCITATION EACH UNIT		ALL SWITCHING 72 KV.	SINGLE POLE STICK OPERAT'D		SECTIONALIZED RING BUS
SEAL BEACH	HIGH VOLTAGE SWITCHING	110 K.V.			110 KV.	110 KV. GANG OPERATED	DIFFERENTIAL RELAYS	1 FROM AUX. GEN. 2400V 1 " STA. TRANS.
SUSQUEHANNA		13,200			MAIN BUS	M.B. TO STA. SERV. BUS WITH REACTR		2300V.
CAHOKIA	VERT. ISOLATED PHASE	13,800				REMOTE HAND OP.		
RIVERSIDE	CELL CONSTRUCTION	13,200						
WAUKEGAN		12,000 VOLT DOUBLE BUS			OIL SW. ON GEN. & FEEDER CIRC.		REACTORS ON MAIN BUS & FDR. CIRC.	
VALMONT	GROUPED PHASE	13,800						
HALES BAR		13,200	250 VOLT					
BIG SIOUX		6,600 V			2 STA. SERV. BUSSES CONN.			
NEOSHO								
DRESSER	REMOTE CONT.-INDOOR & OUTDOOR SUB STATION	13,200	230 V.		15-75+132 KV.			
EDGEWATER	REMOTE CONTROL INDOOR + OUTDOOR	6,600						
BARBADOES	REMOTE CONTROL	13,900			3,200V.-O.C.B.			1100V STARTING
PINE GROVE								
IRON MT	REMOTE CONT. INDOOR	13,200	RING BUS SYSTEM	SEE TEXT				
FORDSON								
BROTHERHOOD OF L.E. BLDG								
BETTENDORF								
BAYONNE								

such a way that compartment doors cannot be opened unless the circuit breakers are also opened, while the circuit breakers and disconnecting switches are interlocked in such a way that no circuit is made or broken through the disconnect, that is, it cannot be opened until after the breaker is opened and must be closed before the breaker is closed. This is the arrangement used at such plants as Columbia, Richmond, Avon, Edgar and others.

Disconnects are of various types, depending on the original design of the electrical system. At Columbia 15,000-v., remote, hand-operated disconnects are used. At Richmond these disconnects are of the 3 and 6-pole type, gang-operated. Long Beach uses the single-pole type of stick-operated disconnects, while Seal Beach uses 110-kv., gang-operated disconnects.

Figure 2 shows a single line diagram of the switching used at Big Sioux station. Here the generators send power at 6600 v. to two banks of 12,500-kv-a. transformers with delta-connected primaries and Y-connected secondaries. These transformers are connected to the tie busses between the two main busses, which, in turn, are sectionalized and interconnected by proper circuit breakers and switches to feed the outgoing circuits. Station service is obtained from one of the tie busses through a bank of 33,000-v. to 550-v. transformers.

Safety devices consist usually of reactors between units in the main bus and on the various feeders.

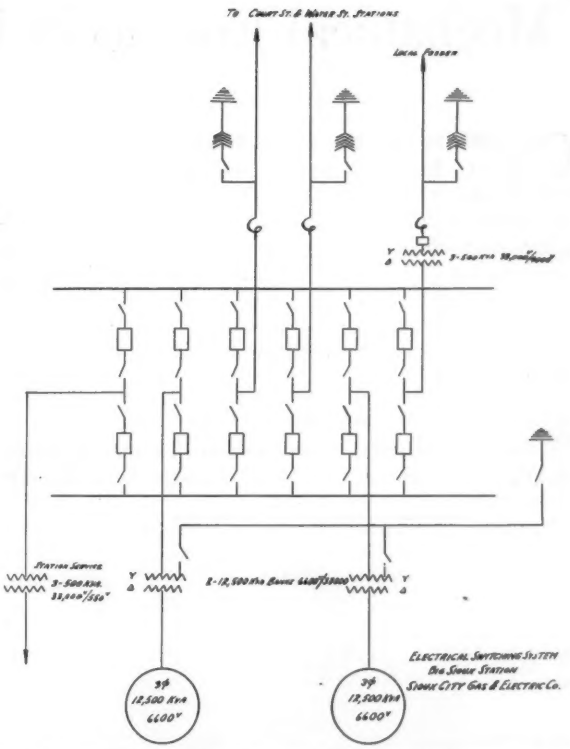


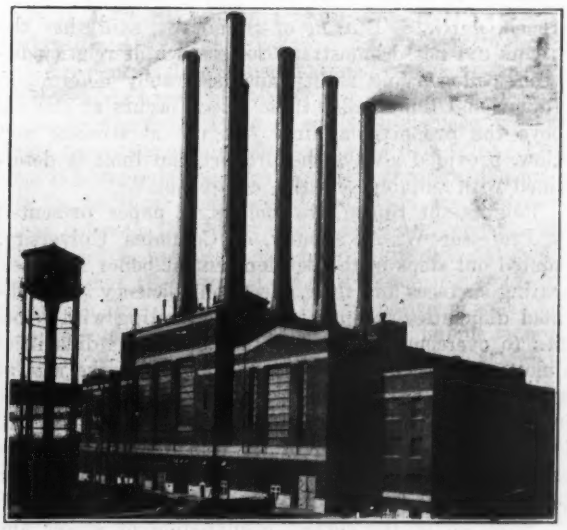
FIG. 2. SINGLE LINE DIAGRAM OF BUS ARRANGEMENTS AT BIG SIOUX

Auxiliary Supply

The varied conditions at these plants make necessary varied arrangement of the auxiliary bus. At Philo, for example, auxiliary service is obtained from a bank of transformers directly connected to the generator leads. At Trenton Channel two separate auxiliary systems are used, one for d.c. and one for a.c. The electrical equipment in the pulverized coal preparation house is driven by a.c. motors to eliminate the disadvantages and dangers of commutators, while many of the other auxiliaries in the plant are driven by d.c. motors. The supply for both types is provided by separate steam-driven, a.c. and d.c. generators. At Somerset station power for starting the auxiliaries is taken from the station service bus with a throw-over to the auxiliary bus after operation has begun. The same arrangement is used at Barbadoes Island station, where a separate 1100-v. starting bus is provided for the auxiliaries.

At the Iron Mountain plant an interesting bus arrangement is used made necessary by the unusual distribution of equipment in the plant. The power generated is a.c. but, since most of the motors in the industrial departments are d.c., various substations are located about the plant containing motor generator sets. These serve not only to provide flexibility of drive for the motors but, since the motor of the motor generator set is a synchronous motor, considerable control over power factor is obtained. A ring bus system for the excitation of these synchronous motors is provided, which can be used in the main power house, if necessary, while a separate steam turbine driven exciter is also provided for normal operation.

FIG. 1. HYDRAULICALLY OPERATED SWITCH MECHANISM AT CRAWFORD



THE FORDSON PLANT OF THE FORD MOTOR CO.

Mechanical Engineers Discuss Power Problems

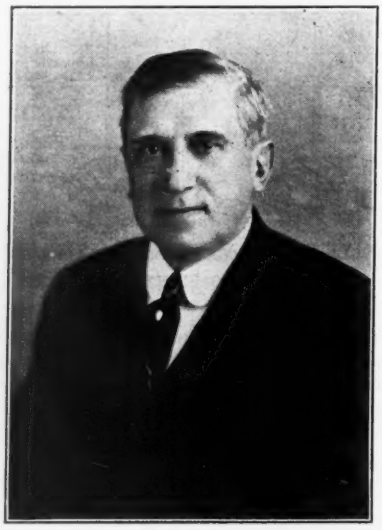
POWER FUELS AND HEAT TRANSMISSION DISCUSSED AT THE ANNUAL MEETING OF THE A.S.M.E. IN NEW YORK, DECEMBER 6 TO 9

CHIEF AMONG the topics at those sessions of the Society in which power problems were discussed were Smoke Abatement, Heat Transmission, By-Product Processing of Coal and Central Station Power. In addition there were several reports of committees and the presentation of results of research committees including those on steam tables and on boiler feed water.

Several of the papers presented, of importance to power plant operators, will be abstracted at length in subsequent issues.

INDUSTRIAL POWER

At the Industrial Power session, Tuesday morning, A. E. White and C. L. Clark submitted preliminary



CHARLES M. SCHWAB, PRESIDENT OF THE AMERICAN SOCIETY OF MECHANICAL ENGINEERS

results of tests on 0.13 carbon steel boiler tubing under temperatures of 900, 1000, 1250 and 1500 deg. F. H. J. French, of U. S. Bureau of Standards, said that the authors did not demonstrate the absence of relation between load-carrying ability and accurately determined proportional limits; also that "creep occurs at stresses above the proportional limit but not at stresses well below, provided always the proportional limit is determined with suitably sensitive equipment."

Relation of Stokers to Boilers, a paper presented by Professor W. A. Shoudy, of Columbia University, pointed out steps in the development of boiler furnaces, heating surfaces and their effects on efficiency and indicated difficulties encountered at high rating with remedies to overcome them; also that operating difficulties almost never occur at low combustion rates, the rate at which trouble begins being generally determined by the impurities in the coal. Before the type of stoker can be selected, the character of the coal including relative ease of ignition, per cent of ash content and fusion temperature of the ash, must be known.

Selection of the correct combination of stoker and boiler should be based upon comparisons of operations at certain per cents of rating. Selection should be made along the following lines:

1. Determine the number of boilers that the variations in load and local conditions demand.
2. Select a grate surface of sufficient size to permit of conservative combustion rates.
3. Determine the rate of evaporation that feed water conditions will permit.
4. Select the most efficient heating surface that draft, coal costs and fixed charges permit.

J. S. Bennett, Assistant Engineer, American Engineering Co., Philadelphia, said that low grade western coals have been burned on dump type underfeed stokers for many years with great success but the substitution of more modern underfeed dump stokers for older ones of the same type has shown a marked improvement in the operating results. If anything, higher fuel burning rates can be maintained successfully with the low grade western coals than with the better grades of eastern coals.

FURNACE VOLUME AND RADIANT HEAT

Howard E. Bacon, Westinghouse Electric & Mfg. Co., stated that there should be joint selection of the fuel burning equipment and the boiler, together with other apparatus involved by the plant heat cycle. Contrary to general belief, it is possible to set a boiler too high. The setting height should be determined, not by furnace volume, but from a study of the burning characteristics of the fuel with particular reference to the flame length. Radiant heat forms a large proportion of the boiler heat absorption and its rate varies as the square of the distance between the surface and the source. The boiler should be placed, therefore, as close to the stoker as is consistent with the maximum flame length of the fuel used. Failure of high boiler settings is due primarily to excessive temperatures arising from inter-wall radiation before gases reach the tube surfaces.

Mr. Bacon then indicated that, by slanting the furnace walls more, heat rays are reflected onto the tube surface, thus explaining the effectiveness of an inclined bridge wall in lowering furnace temperatures below the critical point for excessive slag and clinker formation.

Stress was laid on the fact that the former idea that preheated air introduced under stokers would give considerable trouble in forming clinker is unfounded. The exact opposite has been experienced.

R. S. Bayntun of West Point, Va., stressed the point that, in raising the height, we decrease the area of tubes exposed to radiant heat and he felt that as much area should be exposed to radiant heat as possible. With preheated air, the height of furnace could be lowered 3 or 4 ft.

William H. Jacobi of the Springfield Boiler Co. added that it is pleasing to note that we are gradually coming to designate boiler capacity in terms of pounds of steam produced or of water evaporated. The next step should bring us a suitable "unit of evaporation" which will encompass all the conditions leading to a

comprehensive and profitable boiler operation. He spoke of the general impression that the capacity of a boiler bears a direct ratio to the available heating surface as erroneous.

Mr. Jacobi emphasized the fact that the functioning of both stoker and furnace is intimately related to the necessary air and gas flow, therefore we must include the draft equipment in our consideration. The value of draft regulation and gas flow with relation to the nature of fuels and boiler loading seems not to be appreciated. He also deprecated judging furnace performance entirely on production of CO_2. High production of CO_2 means combustion with limited air, but such combustion does not exist uniformly over the entire fuel bed and, in consequence, neither the quality nor the flow of the gases is uniform, with the result that losses are incurred which can not be justified by theoretical considerations. Again, combustion with limited air means high-temperature fires, which facilitate high combustion rates, hence add to wear and tear of the furnace. High combustion rates mean the possible use of small stokers, regardless of the nature of the fuel and here is where the error lies. Stokers are sold on the basis of their ability to burn completely large amounts of coal regardless of the consequences to the furnace and the functions of the boilers above. The CO_2 indication, if used, should be considered along with a greater effort in learning to make and maintain useful fires.

High percentages of CO_2 may indicate waste, as revealed by the ash when operating boilers at high ratings with stokers forced to their utmost. It is better to use moderate rates of combustion.

Smoke Abatement

Smoke Abatement was the topic of the Fuels Division meeting held on Tuesday afternoon, covered by three papers.

Dr. William C. White, pathologist, U. S. Public Health Service, addressed the group on Effect of Smoke on Health. While he was assured of the baneful influence of smoke on health, Dr. White pointed out that data was lacking on the exact nature and extent of the influence of smoke on health and proposed a plan for co-operative research by the City of Pittsburgh and correlated agencies to determine definitely the effect of smoke on health.

Smoke Abatement, Its Effect and Its Limitations was presented by H. B. Meller, Chief of the Bureau of Smoke Regulation, Pittsburgh, Pa., enumerated advantages accruing to manufacturers and the public from smoke abatement. He held that effort should be to regulate plants so that the natural fuel for any district may be used without resultant violations. Ordinance interpretation of smokelessness is based upon draft, combustion space and secondary air. In proportioning stacks, it is necessary to know the normal output of the boiler, the fuel required to secure that output and the draft loss from the ashpit to the stack. For proper combustion in the furnace, sufficient combustion space and a proper proportion and time of admission of secondary air are necessary.

In the discussion of these papers Wm. G. Christy, executive secretary Citizen's Smoke Abatement League of St. Louis, spoke of the necessity of arousing public opinion on the subject, as the efforts of leaders in social, professional and commercial circles should be co-ordinated and directed along fundamentally sound lines.

H. W. Clark of Salt Lake City said the successful smoke abatement department is one which has one or more competent technical engineers, capable of analyzing the plant owner's problem, advising changes to be made and showing the owner how he can soon save the cost of the required alterations by reduced cost of operating his plant.

Supply of Supplementary Air, Important

J. F. Barkley, fuel engineer, U. S. Bureau of Mines, pointed out that the amount of air that should be admitted by special arrangement over the fire was not in constant ratio to the entire air used but varied considerably according to the condition of the fire, the furnace and the method of application. He also said that, while only a slight reduction in the percentage of volatile matter in coal made a large difference in the amount of smoke made, coals of the same volatile content acted quite differently in this respect.

Andrew A. Bato emphasized the advantages of a compulsory course in firing for fireman and cited courses of this kind given under the Prussian Department of Commerce and Industry, graduation in which is required before a fireman may obtain a license.

Professor A. G. Christie suggested that, since each small plant cannot employ a combustion expert, it would seem a logical step for groups of small plant owners to combine and employ an expert for the group. Such a man could not only increase the efficiency of combustion but could save much by purchasing heat units in larger quantity, hence at less cost for the group.

H. W. Clark, speaking of savings made by reduction of smoke, stated that smoke abatement is going to cost much more than has been realized but that any necessary expense will be worth while.

Heat Transmission was discused at a Joint Session with the American Society of Refrigerating Engineers, the program being arranged by the Committee on Heat Transmission of the National Research Council. Abstracts of papers will be given in later issues.

In a paper on Measurement of Static Pressure by Carl J. Fechheimer, Westinghouse Elec. & Mfg. Co., the author described a new instrument for measuring static pressures in air-flow determinations. Made in the form of concentric brass tubes, the outer of which is ¼ in. in diameter, the instrument is easily introduced into air ducts through small openings, such as bolt holes. Pressure is communicated to manometers through two holes, one to the inner tube and the other to the concentric space between the tubes, about 78.5 deg. apart. The instrument is held perpendicular to the flow in such a manner that the direction of flow bisects the angle between the axes of the holes. In this position, which can be determined by balancing the pressures on one manometer, the reading on a second manometer gives the static pressure. The instrument has less error in turbulent flow than other types.

In the Robert Henry Thurston lecture, delivered Tuesday afternoon by Dr. Cecil Howard Lander, director, Fuels Research, Department of Scientific and Industrial Research, London, England. Coal Utilization was discussed covering preparation for the market, low

temperature carbonization, high temperature methods, pulverized coal, and production of oil from coal. Dr. Lander stated that conditions governing the efficient combustion of fuel are now well understood and, if proper control is effected, the thermal loss in unburned products need be only inconsiderable, with solid, liquid or gaseous fuel. The real problem in furnace work is successful application of the heat generated to the purposes in hand. This involves an understanding of the principles underlying heat transfer and the effective utilization of the sensible heat of the flue gases for preheating either fuel or the air for combustion.

By-Product Processing of Coal

At the second session of the Fuels Division discussing By-Product Processing of Coal, A. C. Fieldner dealt with the fundamental principles involved in low temperature carbonization and discussed the present status of representative types of processes, showing that, at this time, the merits of low-temperature carbonization in this country are quite uncertain.

Professor A. G. Christie stated that liquid fuels must be secondary by-products in coal distillation because of our vast crude oil resources and that, since it will be difficult to induce the buyer to pay higher prices for a smokeless fuel than he now pays for bituminous, the market for semi-coke will be in those parts of the country where anthracite is now used. He also pointed out that the lower priced, high-volatile coals will show the greater economic yields from low-temperature distillation.

J. A. Perry told of the advantages to be gained by utilizing slack and low grade fuels in inclined rotary types of low temperature carbonizing plants, also pointed out the process of blending cheap fuels available in England for low temperature carbonization with other coals to produce a good, hard and dense coke.

R. S. McBride described three methods of complete gasification of bituminous coal: 1. By means of a carbonizing plant making coal gas and coke together with either producers or flue gas sets of both for gasifying the coke. 2. By the use of lump bituminous coal in a producer or a water gas set. 3. By use of lump or possibly slack coal in a special type of complete gasification apparatus, supposedly producing a somewhat better or higher grade of gas at perhaps a somewhat higher transformation efficiency than can be obtained by the use of lump bituminous coal in a modified water gas set.

J. A. Perry took issue with the statement that "complete gasification of all the coke would, however, produce a mixture of oven gas blue water gas rather too lean to permit of economic supply" and submitted some operation costs to support his objection.

T. B. J. Merkt of the Brooklyn Union Gas Co., speaking of gaseous fuel in steam raising in industrial plants, said the number of gas-fired steam boilers in use in various industries, such as clothing and chemical, runs well into the tens of thousands and in individual capacities up to 30 boiler horsepower.

K. M. Simpson of New York pointed out that char made an excellent fuel for pulverizing since all moisture, "water of constitution" as well as surface moisture, has been removed by the process of preparation. He also stated that while the corrosion of iron and steel may be due to sulphur content in coal, no corrosive action takes place, if no moisture is present in the coal.

One of the papers presented at the General Topic Session dealt with Stresses and Deflections on Large Dynamo Frames due to Dead Load and was read by M. Stone of the Westinghouse Electric & Mfg. Co. Because of the continued tendency to enlarge the sizes of electrical rotating machinery and, necessarily, the dynamo frames themselves, some thought has been given to the mechanics involved. This paper gave the result of an investigation made by the Westinghouse Electric & Mfg. Co.

Two assumptions are made as to frame supports, namely: that they are either simply supported, or built-in. The actual condition is probably between the two and measurements are being made to determine the relative accuracy of the suppositions. But the first assumption, since it imposes the more severe conditions should be assumed in design.

Tables and equations were given which permit satisfactory design of machines much lighter than now in use. No analysis is made of the effect of unbalanced magnetic pull, all such effects being under the control of the designer in fixing his allowable air-gap variation.

Central Station Power

The session on Central Station Power held under the auspices of the Power Division on Thursday morning had a full program.

H. B. Reynolds, chairman of the division, read the progress report on steam power engineering.

In the next paper, Paul Bancel of the Ingersoll-Rand Co. dealt with operating performance of one type and make of condenser.

In discussion, G. L. Kothny of the C. H. Wheeler Mfg. Co. claimed that finding no essential difference between operating and test performance is not unusual, if the condenser is constantly cleaned. He also said that the difference in the performance of the 1912 weir single-pass condenser and the 1925 Ingersoll-Rand condenser might be due to choking the air outlets by orifice plates and operating the steam jets at different vacuums.

In discussion of a paper by E. B. Ricketts of the New York Edison Co., which gave results of about 50 tests made at weekly intervals during 1925 and 1926 on four condensers, Dr. W. R. Morgan held that tube inactivity is largely due to poor distribution of water to the tubes. Performance of single-pass condensers was held to compare unfavorably with that of well designed, two-pass condensers, because maintenance costs are high due to frequent cleaning, which also reduces the period of availability for service.

Steam Condenser Practice and Performance, by F. J. Chatel of the Detroit Edison Co., dealt with results in the four plants of that company. Performances from the original installations to those of the present time showed a marked improvement, which indicated that condensers of the single-pass type, within a range of from 0.95 to 1.05 sq. ft. of surface per kilowatt of turbine capacity should be considered good practice. Their performance seems to outweigh the fact that a larger amount of water is necessary for this type than for a two-pass condenser or a condenser having more tube surface.

In discussing this paper, C. D. Zimmerman added that two other factors in connection with condenser vacuum have had insufficient consideration:

1. Steam leaving the last blades of the turbine is at a high velocity and in a highly turbulent condition. There is evidence that this steam does not meet the condenser surface evenly but "piles up" in certain sections. It is possible that improvements can be made in the connections from the turbine to the condenser which will lead to improved condenser performance.

2. Steam leaving the last turbine blades enters an open space without stream lining, which is analogous to using no orifice in places where an efficient nozzle should be used. This sudden increase in area of passage causes violent eddies and turbulence, as the steam changes from a high velocity on leaving the last blades to a lower velocity on entering the condenser shell. Due to this turbulence, this change in state is accompanied by an appreciable increase in entropy and a consequent loss in the availability of the energy which, for the same vacuum at the top of the condenser, might be utilized in the turbine itself.

Messrs. W. J. Wohlenberg of Yale University, and E. L. Lindseth of the Cleveland Electric Illuminating Co. discussed the Influence of Radiation in Coal-Fired Furnaces on Boiler Surface Requirements and a Simplified Method for its Calculation.

Application of the method outlined yields information concerning that division of total surface between cold furnace walls and convection zone which results in greatest overall energy absorption. They indicated that the method of calculating radiation from projected area rather than from actual surface of water-cooled wall, is correct. Their results also indicate that the present tendency toward using highly preheated air and decreasing accordingly, the boiler surface, is based upon sound theoretical consideration.

The fact was also cited, at a recent meeting of the French Society of Civil Engineers, that, with long flame burning, the combustion chamber is required to be twice the size of that where short flame fuels are used. Also, in France, smaller sized combustion chambers are now being used. Clear atmosphere in the furnace is important as the interference with radiation of particles held in suspension reduces the efficiency of heat transfer where furnace atmosphere is dense.

B. N. Broido pointed out the influence that water-cooled walls have upon exit gas temperatures and also upon the efficiency of the boiler. There is a certain ratio between the boiler surface and the water-cooled surface which gives the best results in total efficiency of boiler. One of the reasons of the comparatively small effect of the water-cooled furnace surfaces on the efficiency of the boiler is that, with increasing surfaces in the furnace, the heat absorption per square foot of heating surface is reduced.

V-Notch Weir Measurements

Accuracy of the V-Notch Weir Method of Measurement by D. Robert Yarnall of the Yarnall-Waring Co. presented tests of such a weir having a capacity of one million pounds per hour.

From many tests which have been made with the apparatus described in the paper, the author held that anybody who used the co-efficients corresponding with any given head, as given by one of the curves, can obtain accuracies within ½ of 1 per cent.

In discussion, C. C. Trump of Philadelphia added that viscosity affects coefficients of weirs and orifices with sharp edges. The higher viscosities give less contraction and higher coefficient, contrary to ordinary expectation.

Professor W. S. Pardoe of the University of Pennsylvania pointed out that the V-notch weir is not a device of high accuracy and indicated the percentage of error to be expected. He added that the V-notch weir finds its greatest usefulness in the measurement of a quantity which varies greatly and still gives moderate heads for the largest rates.

Feed Water and Its Treatment

At the Boiler Feed Water Session, the sub-committee on Water Softening by Chemicals submitted its report on Pretreatment of Boiler Feed Water which was read by C. R. Knowles.

Topics covered in the report were:

1. The chemical reactions to be considered in the light of present knowledge of physical chemistry, with special attention to the hydrogen-ion concentration of water and its influence upon the precipitation of hardening salts.

2. Compilation of operating data to determine the relative value of continuous and intermittent softeners.

3. Collection of operating figures showing the efficiency of subsidence tanks and basins in order to be able to submit recommendations for the more efficient design of basins for precipitation of solids and the removal of sludge.

4. The causes and prevention of retarded chemical reaction.

5. Standardization of rates of filtration employed for the removal of suspended solids from softened water.

6. The effect of siliceous material as a filtering material when used in conjunction with hot chemical softeners and the value of non-siliceous filtering material.

7. A consideration of the economic value of lime-soda softener treatment preliminary to zeolite softeners or to evaporators.

8. Standardization of nomenclature employed in the field of softening of water by chemicals and of the apparatus and appurtenances in use in these systems.

C. W. Faulk read the report of the sub-committee on Zeolite Softeners, Internal Treatment, Priming and Foaming and Electrolytic Scale Prevention. This report clearly showed the lack that exists of exact knowledge regarding priming and foaming.

Foaming, it was stated, is thought to be due to the presence of substances which concentrate either in the surface or in the mass of the water. Two conditions cause the formation of foam; (1) the presence of something which, by modifying the surface of the water, makes possible the formation of bubbles; and (2) the presence of something which by imparting viscosity to the films stabilizes them—that is, prevents them from bursting immediately after forming. It was shown that organic matter may cause foaming. Need for a foam test was expressed.

In discussing "priming," the fact was brought out that it is possible to heat water in an open flask above its normal boiling point for the pressure of the moment, creating a certain small amount of superheat which, when broken up, causes violent ebullition because of the dissipation of the stored up energy due to the superheat.

Two outstanding methods of reducing foaming and priming are (1) reduction of the concentration of sodium salts, suspended solids, or other offending substances by blowing down the boiler; and (2) the introduction of castor oil into the boiler water.

Embrittlement of Metals

Professor A. G. Christie, chairman of the sub-committee on Embrittlement of Metals, presented its report.

Outstanding facts as follows represent the present status of knowledge of the phenomena:

1. Embrittlement of boiler metal is an established fact and not a myth as believed by some engineers.

2. The difficulty has been encountered in many sections of the country, although, in certain areas, failures of this kind have been more prevalent.

3. In most cases where these failures have been experienced, the water has contained relatively high concentrations of carbonate, bicarbonate, or hydrate of soda and these waters have been low in sulphates or chlorides of soda. Some cases of embrittlement of boiler metal have occurred, however, with waters having low concentration of sodium salts.

4. Embrittlement is a function of excessive stresses in the metal and the phenomenon apparently never appears in the absence of stresses beyond the elastic limit for the metal.

5. It has been shown experimentally that embrittlement of boiler steel may be produced at will in the presence of excessive amounts of hot caustic soda (20,000 grains per gallon) when the metal is under tension beyond the elastic limit. The phenomenon usually takes place by the combined action of high stress and high chemical concentration. These facts have been established by laboratory experiments but the element of time affecting the phenomenon has not been established.

6. Laboratory experiments and practical experience indicate that the embrittlement of the metal may be inhibited by maintaining a specific ratio between the sodium carbonates and sulphates present in the water

7. Failure of the metal progresses by intercrystalline fracture, with, in practically all cases, no deformation of the grains.

8. One investigator has determined that a similar phenomenon may be produced by calcium nitrate. Various investigators are by no means in accord concerning the basic cause or causes of the phenomenon and much discussion has arisen as a result of the two schools of thought. There are certain points, however, upon which there seems to be general agreement. These are as follows:

(a) Brittleness of boiler steel may occur in the presence of high concentration of caustic soda and result from straining the metal beyond the elastic limit.

(b) Failures of this kind are intercrystalline in character.

(c) The cracking of metal occurs, in practically all cases, along the line of rivets and on the dry side of the plates.

Certain investigators believe that the brittleness of metal is affected by the absorption of cathodic hydrogen and that the rapidity of the action is accelerated by stresses in the metal. This view has not received universal acceptance. Still others hold that embrittlement is due to the presence at the grain boundaries of impurities such as iron sulphide, which are dissolved by the action of caustic soda or other chemicals.

Some engineers believe that embrittlement is due partly to certain inherent characteristic of the steel and partly to stresses from deformation and riveting in the process of manufacture, augmented by the stress due to the working pressure in the boiler. Evidence has been submitted to confirm this view.

Boiler Corrosion

Corrosion of Boilers and the Effect of Treated Water in Accelerating or Relieving These Troubles was the subject of a report read by F. N. Speller.

More active investigation of boiler corrosion by representatives of both locomotive and stationary boilers was urged by the Committee. To accomplish this object, the following procedure was suggested.

1. A thorough survey to be made of important work already done on boiler corrosion. This may involve the preparation of a condensed bibliography.

2. A laboratory study to be made of the important factors involved in boiler corrosion and of means for corrosion prevention. This phase of the work will include, for instance, a study of the influence of alkalinity combined with common salts and oxygen in solution and other variables. Such work should be done under boiler temperatures and pressures.

3. A supervised application to be made of the most promising preventive measures under various service conditions.

To carry out this program, it will be necessary to obtain the full-time service of a technical man who has had previous experience in working out corrosion problems, which will involve some expense. The committee is now considering this plan and ways and means by which it may be carried out but, at present, nothing definite has been decided. Much valuable work has been done by individual investigators and important results in combating corrosion have already been attained. It is felt that it is of primary importance to prepare carefully a plan of investigation before undertaking any co-operative research of this kind.

Power Situation in New Jersey

"IN PLANNING to meet the state's future electric requirements, we must look for the most economical and efficient sources of supply whether they be within or without its boundaries," declared Thomas N. McCarter, president of Public Service Electric & Gas Co., in a paper read before the New Jersey Utilities Association in session at Atlantic City on Nov. 20.

"New Jersey has no coal mines, and it has practically no water powers capable of development. In both these respects adjoining states are more fortunate and interconnection makes it possible to share in their advantages."

For every horsepower of load carried in 1925 by New Jersey companies, 2½ hp. will be demanded by 1935 and more than 5 hp. by 1945, said Mr. McCarter, who cited the certain electrification of the steam railroads, the growing number of industrial companies that turn to central station companies for power, and the increasing use of electricity in the home as factors which are creating the demand.

"The electrification of the steam railroads operating in the more populous sections of the state is coming," he told his auditors. "The question is not whether the job shall be done but is rather of the time when financial and other conditions will best permit it to be done."

The load carried by New Jersey companies in 1925 amounted to 450,000 kw. In 1935 it will be 1,125,000 kw. and in 1945, 2,300,000 kw. The problem that the electric utility companies face is the provision, in the best and most economical way, of facilities that will meet this great increase. The executives of the companies represent, said Mr. McCarter, not only their own organizations, but, in this instance the people to whom a dependable supply of electricity has become a necessity. "Upon the judgment we now use and the wisdom we now exercise," he added, "will depend in large measure not only the quality but the cost of electric service to be provided 10, 20 and even more years in the future."

Pointing out that the value of the plant and equipment of New Jersey electric companies had, according to government figures, increased from $69,000,000 in 1917 to $143,300,000 in 1922 and that since that date Public Service had expended some $75,000,000 for improvements and other New Jersey companies a further large amount, Mr. McCarter said that in view of the unquestionable economics of interconnecting adjoining and contiguous systems, he doubted whether the demand of the future could be met as it has been in the past by the provision of facilities serving a limited area only.

"'Super power,'" he said, "is a name designed to appeal to the imagination; 'giant power' is a dream with all the impracticability of a dream, but 'power interchange,' is a development of the electric industry that has its origin in the economic laws that govern the generation and transmission of electricity.

"Interchange of power between systems is calculated to prevent duplication of investment and by permitting full utilization of the output of power stations over a wide range of territory, it will allow the generation of power in the most efficient stations, except under peak load conditions; it will work to cut down the peak load of individual systems; it will provide for quick relief when the service of a system is interrupted by accidents; it will for considerable periods relieve companies from the necessity of large capital expenditures; it will reduce investment in total reserve capacity, and it will allow construction programs of participating companies to be staggered."

Power interchange will, because of conditions peculiar to the state, prove of particular benefit to New Jersey, Mr. McCarter said, pointing out that the peak load of the territory along the coast came at 8 p.m. in the summer months and the peak load for the industrial section of the state at 5 p.m., in the winter months, making possible the use of the winter surplus capacity of interior plants on the coast during the summer, and vice versa. Power interchange between New Jersey and the Pennsylvania mining districts would also be mutually advantageous. Work at the mines stop at 4 p.m., releasing a supply of energy that would assist in meeting the 5 o'clock New Jersey peak. The New York Edison Company, because a large proportion of its business is lighting, is at any time between May and October subject to a "thunderstorm peak," a sudden darkening of the skies that causes the turning on of literally hundreds of thousands of lights and adds as much as 200,000 kw. to its load, and while New Jersey companies do not face a similar condition, they too are subject to sudden demands that tax their resources. Power interchange would level these peaks and save investment in apparatus used only to meet them.

If power interchange were now effective in New Jersey alone it would mean a saving in combined capacity of 60,000 kw. out of a total combined capacity of 647,000 and in ten years would result in a saving of $15,000,000 in investment. If the interconnection were extended to adjoining states, the saving in investment by 1935 would amount to $60,000,000.

Mr. McCarter mentioned as possible sources of future electric supply for New Jersey, the Conowingo station on the Susquehanna between Delaware and Maryland, mine giant stations now being and to be constructed in Pennsylvania, the St. Lawrence river, the Adirondack and the Delaware river developments.

"Power interconnection is the next great forward step in the progress of the electric industry towards the goal of complete service to the people of this country," said Mr. McCarter in conclusion. "It is accomplishing great things and will accomplish greater. New Jersey should not lag behind in its development. In no state is an adequate electric supply more necessary to public welfare and in few states can power interchange play a more important part in securing it. Its foundation is co-operation within the industry and between the industry and the communities served. Its results will benefit everyone."

Merger of New York Utilities

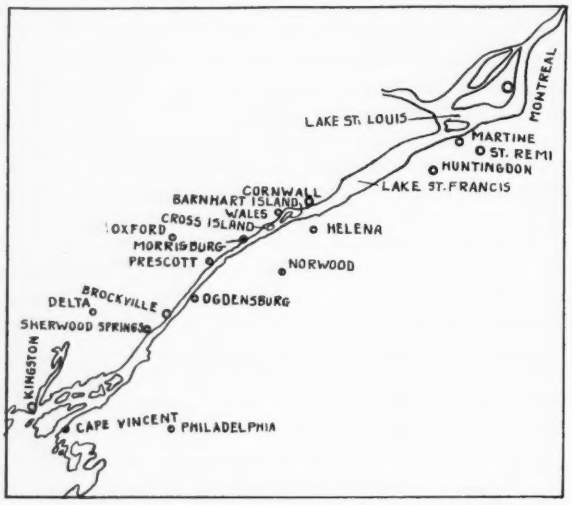
PLANS ARE BEING arranged for the early consolidation of six light and power companies, serving the central Hudson Valley, New York, including the Central Hudson Gas & Electric Co., Poughkeepsie and Newburgh; Dutchess Light, Heat & Power Co., Rhinebeck; United Hudson Electric Corp., Poughkeepsie; Kingston Gas & Electric Co., Kingston; Ulster Electric Light, Heat & Power Co., Saugerties; and the Upper Hudson Electric & Railroad Co., Catskill. The new company will take the name of the Central Hudson Gas & Electric Corp., and with its subsidiaries will serve all portions of Greene, Ulster and Albany counties on the west bank of the Hudson River, and Columbia, Putnam and Dutchess counties on the east bank. The organization will be capitalized at $10,000,000, with 400,000 shares of common stock, no par value. In connection with application for permission to carry out the merger, authority has been asked for the immediate issuance of a block of preferred stock of about $3,000,000. The consolidated company plans expansion in the different sections, including transmission line construction. Thaddeus R. Beal, president of the Central Hudson company, is expected to head the new organization.

MEN WHO deliberately evade wearing goggles when engaged on any job where there is a possibility of endangering their eyesight should be discharged, says Charles E. Hill, vice-president of the National Safety Council.

Power Development of the St. Lawrence River

5,000,000 Hp. to Be Made Available, Also Navigation for Seagoing Vessels Up to 23-Ft. Draft at an Expense of $620,000,000 to $650,000,000

REPORT has recently been made by the Joint Board of Engineers appointed by the governments of the United States and Canada upon the improvement of the St. Lawrence River between Lake Ontario and Montreal for the purpose of making it navigable for seagoing ships. Also the developments needed to raise the levels of the Great Lakes so as to improve the harbors and channels with the purpose, eventually, of giving a passageway from the lower end of Lake Michigan through to the ocean of 25 ft. in depth. Raising of lake levels and the 25 ft. channel from Chicago to salt



SECTION OF ST. LAWRENCE RIVER WHICH IT IS PROPOSED TO IMPROVE

water is purely a navigation project, the power development coming entirely in the St. Lawrence river between Lake Ontario and Montreal.

Present lake navigation operates nominally on 20-ft. draft except in the Welland canal which has 14-ft. draft between Lakes Erie and Ontario. This canal is now being enlarged and deepened to 25 ft., with sills of the locks 30 ft. in depth to take care of further possible enlargement. The board has recommended that 25 ft. be the depth of the ship channels from Lake Ontario to Montreal as the saving by reducing the depth to 23 ft. is not great and there seems no call at the present time for expending the additional amount necessary to provide a 30-ft. channel.

Navigation Is the Primary Consideration

Emphasis is laid by the board on the necessity for making the navigation interests of the St. Lawrence River of primary importance, all power developments and control of lake and reservoir levels being regulated to meet these navigation interests. Working from this standpoint, it was found that it will not be feasible to utilize the Great Lakes as storage reservoirs for controlling the flow into the St. Lawrence River and the board therefore recommends that compensating works, consisting of weirs be built in the Niagara River near Fort Erie, to cost $700,000, which will raise the low level of Lake Erie by 0.7 ft. but will not interfere with the free passage of ice or with light draft navigation. It is estimated that the compensating works in the Niagara River will raise the level in Lake Huron 0.15 ft. Similar compensating works are recommended for the St. Clair River to raise the levels of Lakes Michigan and Huron by an additional 0.85 ft. at a cost of $2,700,000.

These compensating works are intended to counteract diversions authorized by license in the United States and Canada, the effect of outlet enlargement, diversions for navigation and diversions not covered by license. It is to be noted that the level of Lakes Michigan and Huron is being raised more than the drop due to the diversions. The level has dropped during a number of years past because of the low rainfall and it is felt that the improvement in harbors, utilities and navigation will be sufficient compensation for the extra expense in bringing the lake levels back to their condition before this prolonged dry cycle took effect. Some lowering of the lakes would result from the increase of navigation channels to a depth of 25 ft. and compensating works will probably be necessarily increased somewhat in the St. Clair River to take care of this at an estimated cost of $200,000.

To improve the channels between Lake Erie and Lake Superior so as to give 25 ft. depth with the levels which are probably available 99 per cent of the time, it is estimated that the cost of the compensating work will be $3,600,000 and of excavation $41,100,000 or a total of $44,700,000 to give a 25-ft. channel from the head of Lakes Superior and Michigan to Lake Erie. Using compensating works to raise the levels of the lakes will give better depth in the harbors on Lakes Huron and Erie and reduce the cost of improving these harbors and will save approximately a million and a quarter dollars over the provision of a 25-ft. channel by dredging alone.

Developments in the St. Lawrence River

As a matter of development, the stretch between Lake Ontario and Montreal is divided into five parts which the board denominates the Thousand Island section, 67 mi. long, which is deep slow-flowing water without power possibilities from the outlet of Lake Ontario to a point 3 mi. below Ogdensberg, New York; the International Rapids section, from Ogdensberg 49 mi. to the head of Lake St. Francis, a little above Cornwall, Ontario; the Lake St. Francis section, no power development, extending from Cornwall 26 mi. down stream to the end of deep water; the Soulanges, covering 18 mi. of rapids and shoal water from Lake St. Francis to Lake St. Louis; the Lachine section, embracing Lake St. Louis and the rapids and shoals of this lake to Montreal Harbor, a distance of 23 mi. In the Thousand Island section and the Lake St. Francis section are no power possibilities and development is a matter of excavating channels for navigation. The other three sections can be improved for power.

In planning for power houses, capacity has been pro-

posed for the maximum flow which the board considers as utilizable in the future. Navigation requires that the flow down the St. Lawrence be maintained at a high degree of uniformity, hence the hourly flow cannot be regulated to meet fluctuating power demands. Capacity well in excess of the minimum flow of the river has been estimated but for initial expenditures, an installation at 50 per cent of the eventual capacity has been considered so as to avoid investment in power machinery before the power can be marketed.

Winter Operation

Power sections of the river have so rapid a current that they always run open throughout the winter but, during the freezing season frazil and anchor ice form and are carried down by the current so that they pack under and against the sheet ice in quiet water, thus gorging the channel and raising the water level from 10 to 30 ft. at the foot of each open section. Such a condition would seriously decrease the head in the power houses and it is, therefore, necessary to guard against throttling of the river by the gorging of the channel at the upper ends of the pools which will be formed by the construction of dams. Investigations show that, with temperatures obtaining in the St. Lawrence regions, from 15 to 20 cu. ft. of ice will be formed in the course of a severe winter for every square foot of open water but that, in all cases where current velocity is as low as 2¼ ft. a second, the frazil and anchor ice consolidates on the surface and extends the sheet upstream without excessive gorging. Throttling of the river and gorging occur only at higher current velocities. Plans for power development are, therefore, based on enlarging the upper reaches of the power sections by excavation so as to insure current velocities not exceeding 2¼ ft. per second, except for short distances at the upper ends where the remaining area of open water would produce too little ice to be of serious consequence. With ice sheets extending down to the intakes of the power houses and the gorging prevented, operation of the plants will be nearly, if not entirely, free from ice difficulties.

In the Thousand Island section the only improvement required is the removal of certain reefs and the cutting back of projecting points so as to straighten and deepen the channel. The cost of these improvements has been determined as $1,100,000.

Power to Replace Rapids

In the second or International Rapids section the river runs in a succession of rapids extending to a little above Morrisburg, Ontario. It begins with the Galop rapids, near the head continuing in Rapide Plat just above Morrisburg and extending with the Long Sault above Morrisburg, Oontario. It begins with the Galop rapids which terminate near Cornwall, Ontario. Total fall through this section at mean river stage is 92 ft. of which about one-third occurs in the first 18 mi. above Ogden Island and the remaining two-thirds below that point. In developing this section, the present board feels that provision should be made for the fullest possible use of the river for navigation and also for the most practical utilization of power resources. Two plans have been prepared, one with a single dam at Barnhart Island, giving 85 ft. summer and 75 ft. winter head, and with control gates at Galop Island; the second for a two-stage development with two pools, the lower one having a dam also at Barnhart Island, 67 and 63 ft. head, and the upper one having a dam and power house at Ogden Island, just above Morrisburg, Ontario, 17 and 12 ft. head.

In the single-stage development, ships would pass from the lower end of the pool through a canal with two locks on the United States side of the river, returning to the river in the south channel at Cornwall Island, thence by free channel to Lake St. Francis. With the two-stage development, ships would pass through a lock at Ogden Island and from the lower pool to the south channel at Cornwall by a canal with two locks as in the single-stage scheme.

Based on the flow which it is expected will be economical to use, installed capacity of the power houses of the single-stage development would be 2,326,000 hp., while the capacity of the power houses for the two-stage development would be, for Barnhart Island, 1,808,600 hp., and for the Ogden Island plant 406,000 hp., or a total of 2,215,000 hp. More enlargement of the channel to prevent gorging of ice will be necessary in the two-stage development than for the one stage, also the cost per horsepower for installation of the low-head Ogden plant will be greater than if all power be developed in a single stage.

Estimates for cost are, for the single-stage development, including channel enlargement to secure satisfactory winter operation, $235,000,000; for the two-stage development, $264,600,000. The United States section of the board recommends the single-stage development as affording better navigation by eliminating one lock and giving rather more power at a cost of $29,600,000 less than for the two-stage. The Canadian section of the board feels that the two-stage development can be carried out in two parts, so that the power from the upper development can be marketed before the whole of the improvement is completed and, for this reason, its overall cost, including interest charges, will be not greatly in excess of that for the single-stage development. Furthermore, the flowage of land will be reduced from about 28,000 a. to about 18,000 a.

For the dam at the lower pool, two sites are available, one at the head of Barnhart Island, running to Long Sault Island, thence to the United States shore; the other across the main river at the foot of Barnhart Island. Either site has suitable foundation for a dam but the location at the head of Barnhart Island would necessitate a canal 6.9 mi. long, while that at the foot of the island would reduce this length 2.9 mi. So far as the power development is concerned, either plan is regarded as satisfactory. The United States engineers prefer to locate the dam at the foot of Barnhart Island, because of the reduction in length of the canal and less chance of local ice difficulties in winter. The Canadian engineers prefer to locate the dam at the head of Barnhart Island, because of the higher rock foundations found. It is considered that choice between locations will be settled when the type of development has been determined.

Whether single-stage or two-stage development is selected, operation of the sluice gates to control flow of the river should be under the control of an international board with full authority to insure regularity of flow in the interests of navigation in the lower river

and of the power houses downstream, as well as to maintain the level of Lake Ontario within proper limits.

Improvement for navigation only would require a side canal on the American shore, from the Galop rapids to Ogden Island, where a pool would be formed by a dam at the head of the Long Sault rapids; thence ships would pass to the river at Cornwall through a canal similar to that proposed for the two-stage development. Navigation by this plant would be far inferior to that provided by either power development and the estimated cost would be $79,000,000.

For the single-stage development, initial expenditure to open navigation and provide installed horsepower of 1,163,000, would be $190,000,000. For the two-stage development, to open navigation and provide 406,400 hp. in the upper plant and 756,600 hp. in the lower plant would cost $238,400,000, or, if the power development of the upper plant be deferred and 1,163,000 hp. be developed at the lower plant, the cost would be $214,500,000. It would thus seem that, whichever plant is adopted, the expenditure required to produce an initial installation of 1,163,000 hp. above that required for improving navigation alone would be between $100 and $116 per horsepower.

Dredging through Lake St. Francis to provide a suitable ship channel is estimated to cost $980,000.

Power Developed in Stages as Needed

In the Soulanges section, the river falls in a succession of rapids, a total of 83 ft. Certain power developments have already been established in this section, the most important being at Cedars rapids, which uses a third of the low water flow of the river at 32-ft. head, and has installed capacity of 197,000 hp. Recommendations are that navigation and progressive development of power be combined in this section, only the first part of the power development being initially undertaken.

At the head of Cedars rapids the river is to be dammed, creating a pool from 1½ to 5 ft. below the level of Lake St. Francis, since raising to the full level of the lake would destroy large areas of agricultural land. Navigation will pass around the rapids between the lake and this pool by a canal 3 mi. in length with a low-lift lock. A second canal 5 mi. long with two lift locks will carry navigation from the pool to Lake St. Louis in the next section of the river. Immediate power development proposed is 382,000 hp. at the dam with 22-ft. head, continuing the present Cedars plant and feeding it through sluice gates. The second part of the progressive development will be an installation of 500,000 hp. at 75-ft. head at a power house on the shore of Lake St. Louis north of Cascades Point, water to be supplied through a headrace canal formed in part by enlarging the navigation canal. The third step in development will be a dam and power house at the Cascades rapids with 53-ft. head, to develop 974,000 hp., at which time the present Cedars plant would be put out of commission.

Estimated cost for this work is, for the first step, including navigation development, $103,945,000; for the second part, $37,291,000; for the third part, $63,816,000, or a total of $205,052,000 with total horsepower developed of 1,979,700. By installing only half the hydraulic machinery in the first step of the development the initial cost will be reduced to $92,000,000, and the initial horsepower developed will be 202,000. By considering the cost of development for navigation alone, along the lines recommended, it is found that the cost incurred for the initial power development will be in the region of $28 per horsepower capacity and for full development, $87. In case it is impossible to arrange for meeting the initial cost of power development through the co-operation of power interests, the Canadian section of the board favors the construction of a lateral canal on the south side of the river, which will be useful for navigation only and would be abandoned when power development is undertaken. The United States section of the board believes that freer navigation of an open river will be necessary, eventually, and that, in case power development at the start proves inadvisable, it will be better to develop as outlined, building only the foundations for the power plants and leaving further construction to be taken care of later.

Lachine Rapids Power Development Deferred

From the deep water at the head of Lake St. Louis to Montreal Harbor, the first 11 mi. are through deep water, then comes 4 mi. through shoal water at the foot of the lake, next 5 mi. with swift current through a channel obstructed with rock reefs. At the end of this section is the shoal Lachine rapids, 5 mi. in length, and beyond, a mile of shoal swift running water to the harbor. Total fall through the section is about 48 ft., of which only 9 ft. is between the upper end of Lake St. Louis and the head of Lachine rapids, 24 ft. being through these rapids and the other 15 ft. from the rapids to Montreal. The river here describes a wide bend to the south, also some water is received from the Ottawa River by channels from Lake of Two Mountains.

Examination of the possibilities of utilizing the section of the river above Lachine rapids for navigation and developing power at these rapids disclosed that the cost of excavation would be excessive and current in the excavated channels would be too rapid for satisfactory navigation. It is thought best, therefore, to use a side canal as the suitable route for navigation between Lake St. Louis and Montreal Harbor, following closely the river bank and with three lift locks and a guard gate. Excavation at the upper level of the canal and through the long shoals at the foot of Lake St. Louis can be reduced by constructing a control dam in the river at the head of the rapids to raise the low water level of Lake St. Louis. Control works would also be necessary in the channels between the St. Lawrence River and Lake of Two Mountains in order to preserve the present distribution of flow of the Ottawa River and prevent reduction in the flow through the main channel of the St. Lawrence River across to Montreal. The entire control work is estimated to cost $2,000,000 in excess of the saving which would be made in excavation cost but these works will reduce the cost of future power development at Lachine Rapids. Complete cost of the navigation improvement for this section is estimated at $53,000,000.

Plans for future development of power on the river at this point consist of two parts, the first, construction of a power canal along the south shore, from the foot of Lake St. Louis to the Lachine rapids, delivering water to a power house on the south shore at the foot of the rapids and discharging into the La Prairie Basin. This

would give 391,000 hp. The main control dam would be at the head of the rapids, at the same location as that proposed to regulate the levels for the benefit of navigation and auxiliary control structures from the outlet of the Lake of Two Mountains would be identical. It would be necessary, however, to change the main control dam from that required simply for navigation purposes. since the navigation dam would have wide openings to prevent formation of an ice jam, while the power dam would be reduced to such dimensions as would afford safe and convenient operation of the gates in winter. Alteration of the navigation dam to that for power purposes would cost about $281,000. It is estimated that this first part of the power development, considering that the dam has already been built for navigation, would be $81,247,000.

The second step in improvement would be development of 422,000 hp. from a power house to be constructed in the main river at the foot of the Lachine rapids, adjacent to that constructed in the first development. The headrace would be formed by a longitudinal wall extending downstream from the control dam to the new power house and by opening the portion of the control dam between this wall and the south shore. Estimated cost of this second development is $41,966,000. Development of the first step in the power program after the navigation improvement will cost $889,000 more than it would if undertaken in conjunction with the navigation improvement but the lack of market for power would seem to make simultaneous development for navigation and power undesirable. Cost for navigation improvement is estimated at $53,000,000, the additional cost for the two power developments, $123,213,000, with installed capacity of 923,000 hp., or somewhat over $133 per hp. of capacity.

The last of the report is concerned with the development of the St. Lawrence River at and below Montreal but no power development is contemplated in this section.

Completion of the waterway so that it can be opened to navigation is estimated to take from 7 to 8 yr. from the time that active work is begun, if all work is done simultaneously so as to assure completion at the same time. The board gives, in an appendix, a complete program for the prosecution of the work.

Rochester G. & E. Corp. Contemplates Hydro Development

SPEAKING at a luncheon of members of the Rochester section, American Society of Civic Engineers, and the Rochester Engineering Society, held recently at the Sagamore Hotel in Rochester, Franklin J. Howes, chief engineer for the Rochester Gas & Electric Corp., explained how the power company proposes to effect both river control and the generation of more than 13,000 electrical hp., in addition to its present capacity, by building a $1,500,000 dam across Caneadea Creek.

"The new Caneadea dam, which we expect will be completed within a year," said Mr. Howes, "will cost about one-tenth the amount proposed to be spent on a larger one at Mount Morris, N. Y., and will make available about one-tenth the amount of water," Mr. Howes said. "The value of the Caneadea storage reservoir, however, will be greater in proportion to its volume than will that of Mount Morris, because a small volume of water can be concentrated at a period of need.

"This Caneadea project includes a dam of the constant angle arch type flooded by the reservoir. At present men are working on the new concrete highway to replace a portion of the present one, which will be flooded by the reservoir. Later, we expect to build a power house near the dam. The latter we plan to have ready some time in 1928.

"The dam will rise 143 ft. above the foundation of the creek bed and will form a pond, or reservoir, 125 ft. deep and 800 acres in extent. The capacity of the pond will be 1,600,000,000 cu. ft. The water, however, will be kept 10 ft., or more below the capacity height, to allow for freshets due to summer and spring rains."

At the foot of the dam will be placed sluice valves through which water can be drawn when it is wanted. Until the power house is completed, the reservoir will be used only for storage purposes. After the plant is equipped it is possible that the station will be used to generate power for use in that neighborhood, the speaker said. The contents of the pond will make available for a period of 60 days, 300 cu. ft. of water per second, and will relieve the Gas and Electric Corporation of the necessity of carrying approximately 9300 hp. in steam and generation capacity. When the power house is fully equipped its capacity is expected to be 4000 hp.

Although Mr. Howes did not state when actual work on the new Mount Morris storage dam would be commenced, it has been officially stated by the power company that the word to proceed with the Mount Morris development would be given as soon as the Caneadea dam is completed. Such being the case there is every reason to believe that the work of removing all trees and buildings from the territory to be flooded by the Mount Morris dam will be started some time during the fall of 1927, so that real work on the gigantic dam may be commenced in the spring of 1928.

Buying Electricity

YOU AND I will speak of our monthly "electric light bill," says an editorial writer in Forbes Magazine (New York). And because we are accustomed to think of it as covering only electric light, we are sometimes disposed to regard it as high. But our electric light bill is no longer merely an electric light bill. He goes on:

"In my own home, for example, we have an electric refrigerator, an electric washing machine, and other smaller electric appliances. What we actually pay for, therefore, consists of various very useful and helpful forms of electrically-done domestic work. In a very real sense, electricity has become a servant in the home. It lightens the duties of wife, maid, cook, laundress. It saves wages. In my judgment, electricity rivals the automobile and the daily newspaper in giving you the most for your money. Our wide-awake National Electric Light Association should institute activities to bring home to every housewife and husband the new idea that what most of us now receive is not a monthly electric light bill, but a bill for domestic wages, a bill for work done in the parlor, bedroom, kitchen, pantry, laundry, a bill which represents a saving both of work and money."

EDITORIAL COMMENT

Appoint Engineers on Commissions

What is the matter with the average commission? Why is so much lethargy, indecision and wrong conclusion so characteristic of them? The personnel of commissions is usually composed largely of lawyers. Today we are seeking more than ever to place men in positions in which they can function most efficiently.

Many of the questions that come before commissions have to do more intimately with engineering than with law. Who is better qualified to pass upon rates than a competent engineer? Formerly we regarded a trinity of "noble" professions, in which law held a place. Today there is no more noble profession than that of engineer. None has higher ideals or stronger ethical standards. None is of greater service to mankind. The lawyer's training is based upon citation of precedent; his ethics place the interest of his client above that of all others. The engineer's training is that of a logical search for unqualified truth based solely upon fact; his ethics include not only the welfare of his client but equally so, society as a whole.

Public service positions of trust are now ably filled by engineers. We have never had a more efficient Secretary of Commerce than Herbert Hoover. No cabinet officer has had greater influence for good than he. An engineer was chairman of the Mayor's Economy and Efficiency Commission of Baltimore which, at little expense, placed the city on a business-working basis, reducing costs of operation to such an extent that some day when other cities of the country wake up they will follow the example set before them. The first city manager was an engineer and those who are most successful today are generally engineers. Engineers are sought for members of Boards of Trustees of universities. Many engineers have become successful college presidents.

Hyphenating the word engineer has become almost a fetish with some people. We now have human engineers, social engineers, procurement engineers, rural engineers and agricultural engineers, most of whom, while glad to adorn themselves as engineers are unwilling to undergo the rigid training required of engineers. Their engineering training usually stopping with some genteel knowledge of some things about which the engineer deals.

At least one prominent engineer and one big business man should be on all important commissions. We wish to emphasize the word "big," as so many civic enterprizes fail because the gullible public is ever willing to put into the hands of mediocre men the spending of their millions.

The engineer has demonstrated his worth. He has won his place through merit. He has grown out of his swaddling clothes. He is no longer satisfied with a hired position in connection with Boards of Decision. He should occupy his appropriate place—that place is on Boards of Decision and functioning in the decisions of organization, policy and finance as well as in production, operation and management.

Engineering Progress Depends on Co-Operation

Just what part the free interchange of information has had in the development of the power industry is virtually impossible to determine. The fact remains, however, that the last decade, a period which produced more real practical developments than any other and raised the industry to an undreamed of position in the financial and industrial world, is coincident with what we may term a realization or admission of engineering as a collective rather than individual achievement.

Pulverized coal, water walls, regenerative cycle, reheat cycle, air preheaters and other developments that stand out as distinctive during this period can be regarded as nothing more than practical applications of ideas which date back many years, some almost to the invention of the steam engine itself.

Long years of gradual progress on the part of few engineers whose names are now history to establish our engineering societies and a longer fight to bring other engineers and manufacturers to a realization that the progress of engineering depends upon co-operative and not upon individual progress has begun to bear fruit.

It cannot be denied that ten men working individually but with complete knowledge of the others' progress will get much farther than the same ten men working in complete ignorance of each other. So it is but natural that different companies, individuals and manufacturers working together reporting results, tests and experiences with various equipment, will raise the standard of engineering much higher than if working independently, each suspicious of the other and wasting effort both in useless precaution and duplication.

Co-operation among manufacturers, operators, engineers and engineering societies brings out the good and bad features in a fraction of the time formerly necessary. Each year makes more complete data and test results of installation and new equipment. This practice, however, is still far from universal but there is continued evidence of a growing co-operative spirit in the industry.

We cannot believe, as some contend, that in making information regarding finished installations public there is any danger of putting others on the same footing. Although others may have the physical data, they lack experience which characterized the original development and, although they may advance, they must of necessity trail behind the leaders by a certain interval.

Progress in central station practice for the last 10 yr. has been, we believe, largely due to the free interchange

of engineering information in the various societies and engineering periodicals and, although this free interchange may have been in a few isolated cases of great disadvantage to certain individuals or firms, we believe it has been largely responsible for the rapid progress witnessed in power plant equipment and engineering during recent years.

Power Standardization Needed

With the possible exceptions of labor and steel products there is no other item as intimately connected with modern industry as power and power production. Fundamentally, this problem is the same for all industries, although in actual practice methods grow up peculiar to a certain industry. Sometimes there is good reason for these practices, although more often they are the result of narrowness, which causes that certain industry to develop within itself rather than take advantage of advances made in other lines.

The paper mill engineer can pick up many valuable pointers by visiting other progressive paper plants but might it not be well to include a central station or two, a steel mill, a textile mill and other industries? Each one is developing new plans and ideas which might, with some ingenuity, be adapted to other industries. Similarly power engineers of mills, steel plants and metallurgical furnaces have much in common which might be pooled to their mutual advantage.

If 1819 different forms of sheet steel could be reduced to 261 with an increase of business and profits to both dealers and manufacturers, surely much could be accomplished in the field of power by co-operation of various industries. Standardization of equipment, elimination of many styles and models to reduce first costs, as well as the introduction and exchange of new ideas and methods, would accomplish much in the way of power cost reduction. This can be brought about only by the co-operation of power engineers in all industries.

Eyesight Conservation

Of the 42,000,000 gainfully employed persons in the United States, more than 25,000,000 are handicapped by defective vision or eye strain. The economic waste resulting from this single source of deficiency is calculated as being in excess of $30,000,000. That is the value of the actual waste and spoilage of material due to improper illumination and defective vision.

Data gathered by the N. E. L. A. shows that only 25 per cent of the 250,000 industrial plants in the country are properly lighted and that a gain of 15 per cent in production would immediately result from better lighting. On this basis, it is estimated that the total economic gain possible through efficient lighting and proper eyesight conservation would amount to over three billion dollars a year.

The problem of eyesight conservation is one of enormous magnitude. Many organizations such as the National Safety Council, the Eyesight Conservation Council and others, are carrying on or launching constructive programs for remedying this condition. But it is the thought of many, who have studied the matter, that, in addition to industrial research and corrective effort, the subject should be attacked as far back as the public schools where lighting conditions have too often been found far below standard. Children are tender subjects and their vision is much more readily impaired by improper illumination than the sight of their elders.

A most important protective measure that is rapidly becoming employed is goggles. But a few years since, goggles were first advocated for those who were subject to flying particles, fumes, gases, intense light, and other vision-impairing elements. Today at least 35,000 men are enjoying full vision who might otherwise have been blinded. Singularly enough, the men who endured the hazards were hard to swing into line. This apathy on the part of the workman has resulted in compulsory use of goggles in many plants. But this drastic measure has resulted in far-reaching benefit so that there can be no logical or sound objection raised against compulsion in this matter.

Proper facilities for eye treatment should always be provided in industrial plants. Serious infections have been caused by one sympathetic workman trying to assist another by removing a foreign particle from the eye with a dirty match, stick or soiled handkerchief. First-aid and medical facilities for caring for eye and other injuries are essential to every establishment.

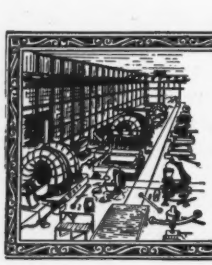
Acknowledgment

The success of any attempt to indicate the trend of development in a particular field of human endeavor depends, of necessity, upon the degree of completeness with which information can be gathered in regard to existing conditions in that field. For it is only from a careful study, classification and analysis of such information that definite conclusions may be drawn.

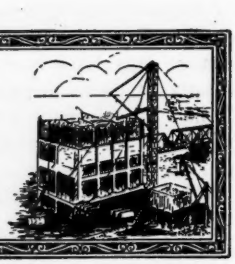
In dealing with such a complex thing as the power plant field, a field which has been characterized by phenomenal progress during the past few years and which is related closely to many allied fields, the gathering of data for an analysis is no small undertaking. It entails the co-operation of not only the manufacturers responsible for the design of new equipment but also that of the operators, who, by their increasingly exacting demands upon the manufacturers, are the instigators of all development. Between these, the operators and the manufacturers, are the designing engineers who act to utilize the products of the latter to the best advantage of the former, and their co-operation, too, is highly essential.

In presenting to our readers the analysis of power plants contained in this issue, therefore, we wish, to express our indebtedness to each of these three agencies for their splendid attitude in complying with our many requests for information. These requests, coming to them, as they did, at times when their own work, no doubt, required all of their attention might easily have been regarded as unnecessary annoyances but with negligible exceptions they met with only the most generous and courteous response. It is to the many who thus co-operated in making this issue possible that we take this opportunity of extending our grateful acknowledgment.

THERE ARE 115 automobile manufacturers in the United States; 15 per cent of them do 90 per cent of the business.



POWER PLANT ENGINEERING DEVELOPMENTS AND NEWS



Fifth New York Power Show Better Than Ever

IN QUALITY OF EXHIBITS, DIVERSITY OF EQUIPMENT FOR POWER PLANT, REFRIGERATION AND INDUSTRIAL ENGINEERS, AND IN NUMBER OF EXHIBITORS, RECENT DISPLAY AT GRAND CENTRAL PALACE EXCEEDS ALL PREVIOUS EFFORTS

GENERAL TRENDS TOWARD the use of higher pressures and temperatures in boilers and prime movers used in power plants during the past year or two, have naturally caused developments in every item of principal power plant equipment, as well as accessories, and this trend was fully illustrated at the Fifth Exposition of Power and Mechanical Engineering, held at the Grand Central Palace, New York City from December 6 to 11, 1926.

Not only from the standpoint of quality of exhibits, but also in number of exhibitors and attendance, this Fifth Power Show surpassed all its predecessors. This year 490 exhibitors, using almost 700 booths, displayed their wares. The total registered attendance at the Show was 23,500, while the total attendance for the week has been estimated at between 90,000 and 100,000 people.

In the field of boilers, economizers, superheaters and such equipment, the use of higher pressures was reflected in the changes in design to produce the necessary strength as well as the resistance to extremely high temperatures. Boiler accessories, such as water gages, soot blowers and the like, were shown for this work, as well as new types of blow-off valves and a boiler draw-off process. Piping and pipe covering, too, designed for high pressure and temperature was of interest.

To meet the new combustion conditions brought about by use of pulverized coal, and the use of boilers at higher ratings, with higher rates of combustion, manufacturers of refractories, refractory cements, water cooled walls of various types, showed many exhibits illustrating the variety of combinations of their equipment that can be adapted to this service.

Several new and interesting types of small steam turbines illustrated the developments that have been made in reducing steam consumption of such units, in improving their mechanical construction to stand high duty service and in their applications through reduction gears for driving pumps, electric generators and the like. Several examples of large high pressure boiler feed pumps, together with many types of regulators for these pumps, aroused much interest.

Particularly interesting were two or three types of combustion control systems of extreme sensitivity, combined with ruggedness, and new types of meters and recorders. In commenting on a meter, developed by the A. S. H. & V. E. for measuring heat transfer through the walls, a most sensitive and interesting apparatus, a local newspaper reporter enthusiastically declaimed that it would measure the blush on a woman's cheek.

Of particular interest to many industrial engineers were the exhibits of mechanical transmission equipment, such as anti-friction bearings, speed reducers, gears and chains, lubricants and lubricating equipment, and the exhibits of wood and metal working machinery, of which there were about eighty or ninety.

Considerable equipment of interest to heating and ventilating engineers was shown by 188 exhibitors. This equipment included valves, thermostatic traps and thermostatic controls for heating systems, unit heaters for industrial buildings, refrigerating and air conditioning equipment and several interesting types of air filters, both of the cell type and of the moving element type.

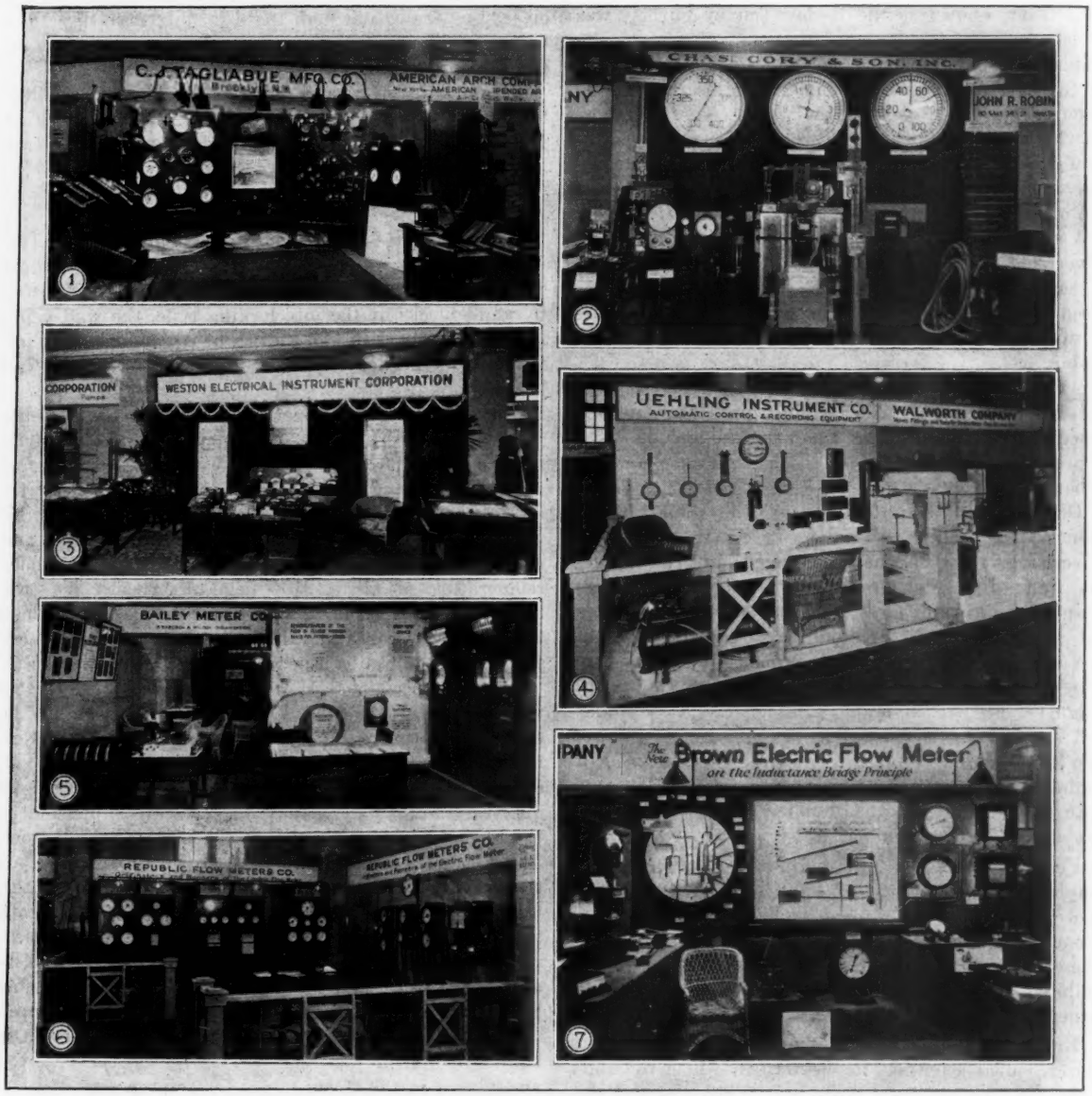
Throughout the Show there was evidence in the design of all equipment of a desire to promote safety to both equipment and operators by rugged design, provision of automatic features wherever possible and devices to indicate proper or improper operation of equipment.

As might be expected, in view of the prevalent interest in pulverized coal burning equipment, a great deal of this was shown. Several types of unit pulverizers were shown, together with new types of burners for producing turbulent action and giving better combustion. Coal and ash handling machinery and coal preparation equipment attracted considerable attention especially two models of the drag scraper in actual operation of handling coal to miniature power plants.

Several educational exhibits attracted the attention of visitors. The Magnus effect, as applied in the Flettner Rotor ship, was shown by motion pictures instead of by a working model, as had first been intended. V. L. Sherman, of Lewis Institute, demonstrated a method for making isometric drawings to scale of complicated piping layouts, which were extremely difficult to show by the standard orthographic projection method. General Electric Co. demonstrated a photo-electric cell to measure minute changes in quantity of light, together with a device by which the movement of the molecules of a piece of steel, while it was being magnetized, could be heard. An extensive program of motion pictures, showing developments and uses of metals, coal, electricity and many other materials, was presented each day at the Show.

At the booth of Combustion Engineering Corp. one of

the interesting items was a full sized Couch burner, designed for forced draft, with a Scene-in-action showing its application for horizontal firing. In this burner was illustrated the method of producing turbulence of the flame by injecting a stream of pulverized coal and primary air and then injecting the secondary air through vanes in such a way as to produce a swirling motion of the stream. This Scene-in-action also showed one of the for vertical firing, designed for forced draft work, was shown, together with a new Lopulco feeder. The burner is designed for introduction of preheated air, is provided with baffles at the nozzle and is designed to handle between 2500 and 3000 lb. of coal an hour. On this feeder changes have been made in the gear drive, improvements in the method of introducing primary air to give better mixture, and a fuel agitator has been pro-



FIGS. 1-7. INSTRUMENT MANUFACTURERS DEMONSTRATED NEW TYPES OF INDICATORS, RECORDERS AND METERS FOR ALL SERVICES

typical combinations of various CE products to form a complete steam generating unit. This unit was made up of a Ladd boiler equipped with a Fin tube furnace, fired by Couch burners, a Lopulco water screen, a C-E air heater and a Combusco ash conveyor. A C-E unit system, as installed at the Cumberland Mills, was also exhibited, showing improvements in the design of the Raymond Impact Mill, which is equipped with a pneumatic classifier, a double cyclone, and a leveler on the cups of the star feeder. A new type of Lopulco burner vided just above the screw to prevent clogging and bridging.

Peabody Engineering Corp. called attention to the Peabody Viscosity regulator, designed to regulate the viscosity of oil being supplied to oil burners, regardless of the quantity or quality of oil involved. Attention was also called to the new three-fold burner designed for burning of oil, gas and pulverized coal.

Fuller-Lehigh Co. exhibited a new type of highly turbulent burner, known as the Calumet burner, de-

signed especially for adaptation to the Bailey furnace wall construction. In this burner, primary air, carrying the pulverized coal, is injected into the furnace through a long, narrow, vertical slot between the water cooling tubes. The secondary air enters through ports on either side of the primary jet, these ports being at an angle with the primary air jet and staggered instead of opposing each other. The burner is made in capacities up to 8000 lb. an hour. Another recent type of pulverized coal burner, known as the Bailey Tenney burner, was also shown. This consists of a center pipe or nozzle through which the primary coal and air are forced into the furnace, an adjustable cone being inserted in the discharge opening to spread the flame. The secondary air, which enters the furnace through the annular space around the center pipe is swirled by the burner vanes to give a thorough mixture of coal and air. This is the type of burner recently installed at Ashley St. Station.

A new type of pulverizing mill, known as the Lehigh pulverizing mill, was also of interest. This is of the air separator type but can be manufactured in the screen type if required. It is available in capacities up to 20 t. an hour and is made for either the unit or the bin system.

At the booth of Neemes Foundry, Inc., was shown a new hand operated stoker, having grate bars proportioned to give ample strength and surface and provision to prevent sifting of coal to the ash pit and wedging of bars.

On the Atrita, manufactured by Riley Stoker Corp., attention was called to changes in construction. The pulverizing rotor is now arranged in two stages, the first, for the preliminary pulverizing, being equipped with manganese steel hammerheads, the second stage having the regular arrangement of round pegs which have been increased in size to 2½ in. A new type of high side grate block and changes in design of the general grate blocks on the Riley underfeed stoker were shown. For the Jones stoker a new type of overhead poppet valve has been designed to eliminate steam leakage. This valve is of the same type as an automobile valve and actuated in the same way by a cam shaft and rocker arms.

Furnace Engineering Co. had on display one of five Simplex unit pulverizers of 4500 lb. capacity, as supplied to a recent power plant showing the motor drive through a Link-Belt chain, the magnetic separator arrangement and the arrangement of the rotor. It also exhibited the Simplex induction type pulverized coal burner.

Erie City Iron Works, in showing the Unitype pulverizer, called attention to the way in which the rotor of the machine had been shortened, to changes and simplification in the pulverizing chamber, the adjustable feed sleeve and the separate motor drive on the feeding device to secure wide feed ranges. This company also showed an example of its new water cooled wall construction, consisting of water tubes surrounded by refractories and a drawing to show how this wall is applied in its three drum boiler to produce what is called the basket type of furnace.

McClave-Brooks Co. displayed a new type of chain grate stoker with mechanical drive, one type designed for anthracite and coke breeze, the other type for all grades of bituminous and lignite. One of the principal features of this unit is the link which can be replaced without stopping the chain.

Vastine Sales Corp. showed a new model of its furnace fire observer for inspecting conditions inside the furnace, as applied to the fin tube wall type of furnace.

Ray rotary fuel oil burners, of a recently developed type, were shown by Preferred Utilities Co., Inc. In this burner an atomizing cup mechanically reduces the incoming oil to a thin film by centrifugal force, and the oil leaving the cup at high speed in tangential direction, is met by an impact of air from the fan, driven at an angle in the opposite direction.

The making of repairs on a National arch was illustrated at the booth of the M. A. Hofft Co. by a motion picture and information was also available on refuse burning equipment.

Furnace Construction

McLeod & Henry Co. called particular attention to its flat suspended arches and to its design of an air cooled furnace wall. This employs specially constructed pyramid blocks of the interlocking type, the wall being laid up usually with two courses of pyramid blocks, followed by a header course. Steel mixture veneer wall blocks were also shown.

In a well arranged and attractive booth the Celite Products Co. featured a small furnace in which a temperature of 2100 deg. was maintained, the top part of the furnace being made partly of Sil-O-Cel and partly of fire brick. This was designed to show how with water boiling in a beaker set on the fire brick, the hand could be rested on top of the Sil-o-Cel with a furnace temperature of about 2100 deg. underneath the two. Sil-O-Cel super brick, designed for service from 2500 to 2700 deg., was also exhibited. Part of the display was devoted to Celite, especially as it is used in concrete.

Power Specialty Co. featured examples of Foster water cooled furnace wall construction, known as the composite water wall. This wall is composed of 4-in. tubes, covered with cast iron blocks which are machined, carefully fitted and shrunk on the tubes. The elements are backed up by refractory tile and are supported at the top by angles, with spring suspension at the bottom. The Foster Composite Water Back for stokers also attracted much attention, as well as the Aero Pulverizer. One of the interesting features exhibited at this booth was a new steam table issued by the company as Publication 211-1, giving the properties of steam up to 1200 lb. absolute pressure and 300 deg. of superheat. This table has been prepared as a result of the recent research work done on the properties of steam. The bulletin is bound in such a way that the leaves can be removed and placed in the steam tables for reference.

American Arch Co., Inc., featured the new American air cooled walls type C, calling special attention to the vertical and horizontal duct connections, the special joints to prevent infiltration of air and provision for relieving expansion strains by allowing for expansion of each individual block.

At the booth of Insulating Products Corp., Webers No. 48 insulating cement, designed primarily for use on flues and ducts, was displayed. This is a silica fibre, with sufficient asbestos added to insure structural strength, and a special clay for a binder. Mixed with water, it forms an easily applied plastic cement.

The Korfund Co., Inc., exhibited a two-ton York motor driven ammonia compressor, set on the new Korfund vibro-dampers, to show the absence of vibration transmitted from the machine. These dampers consist of a spring supported casting bearing the weight of the machine, arranged with Korfund insulating material between this support and the housing and base plate. Horizontal and vertical vibration was measured by a vibro-meter. Korfund Foundations exhibited in mat form, as installed under machines which require heavy concrete foundations, or cause severe horizontal vibrations, were also displayed. The company also showed the Alden turbine condenser expansion gasket, consisting of a hollow rubber gasket containing water under moderate pressure designed for turbine exhaust nozzle joints.

Cork Foundation Co. exhibited standard plate of natural cork, known as Absorbo, for the isolation of vibrating machinery.

Keystone Refractories Co., featured the Keystone Sprayer, designed to shoot plastic refractory materials involving Durastix and Steel Veneer on to furnace walls.

Norton Co. featured a section of a boiler furnace wall as used with stoker settings with Crystolon bricks at the clinker line.

Johns-Manville, Inc., called attention particularly to Superex combination pipe insulation designed for tem-

FIGS. 8-15. FURNACE WALLS, BOILERS, PULVERIZED COAL EQUIPMENT AND ACCESSORIES WERE ATTRACTIVELY DISPLAYED

peratures up to 1500 deg. This material is applied with a protective coating over it of standard 85 per cent magnesia. The company also featured Transite insulated roofing designed to prevent condensation on the underside of roofs.

Bitumastic solution, a coating for the protection of steel and iron, was shown by the Wales-Dove-Hermiston Corp., and the use of Hermastic paints for protecting the inner surfaces of coal and ash bunkers, were illustrated in a miniature coal bunker model.

Botfield Refractories Co. called attention to an arch laid up with Adamant refractory cement, in which the whole weight of the arch, totaling about 115 lb. was supported by one joint between two of the bricks. It was also stated that Adamant is designed to maintain its bond through the complete temperature range to which refractories are subjected. Attention was also called to its use as a binder for chrome ore under severe slag conditions in steel mills.

A working demonstration of the method of placing Hi-tempite cement on refractory walls was given by the Quigley Furnace Specialties Co., using a quarter size model of its refractory gun. Photographs of this gun in use showed that it had been employed in handling cement slurry in marine work with the gun 80 ft. from the working nozzle. An interesting test, using zinc strips with letters painted on them in Quigley triple A solution, and then immersed in concentrated hydrochloric acid, showed the protective action of this coating.

The Liptak type S air cooled wall and type X air cooled wall, designed to be self-supporting, and based on the double suspended arch principle, was shown by Liptak Firebrick Arch Co. as applied to pulverized coal furnaces.

A. P. Green Firebrick Co. called particular attention to 'Sairset Firebrick cement, an air setting cement designed to give a perfect bond without heat, to be applied for all temperatures and under heat to form a smooth, protective monolithic furnace lining.

Drake Non Clinkering Furnace Block Co. showed various types of walls set up with the T and U shape blocks for air cooled walls, in both fire clay and silicon carbide types. The S-X air cooled wall, showing both the vertical and horizontal openings, was also featured, this wall being constructed so that each section is a unit in relation to the whole wall.

Bernitz Super blocks, known as the S-100 series, and made of Carbofrax, were displayed by Bernitz Furnace Appliance Co. In making up a hollow wall with these blocks, both the tee and box locks are used, the design giving a series of vertical ribs to produce substantial construction.

Monolithic furnace construction of new design, using Plibrico, was featured by Plibrico Jointless Firebrick Co., showing the flexible anchors used for securing Plibrico Jointless Walls to allow for vertical and horizontal expansion.

General Refractories Co. directed attention to Biasbrix designed to be set on the bias in laying up the wall, thus producing a self-locking action and minimizing heat leakage. It also displayed examples of Grefco, a high temperature chrome cement.

The Engineer Co. featured the Enco Electric Combustion Control equipment, designed to utilize the overfired draft control principle, combined with pressure regulation. A drop in steam pressure actuates the controller of the forced draft fan, speeding it up, and at the same time adjusts the boiler damper and the coal feed to compensate for the new condition. The regulation of the damper is also compensated for variations in atmospheric conditions.

At the booth of Hagan Corp. another small boiler was set up with commercial type of combustion control equipment to show the centralization of the Hagan control at one point. A master control panel, actuated by variations in steam pressure and load, is operated by compressed air and transmits its regulation pneumatically to the draft equipment, coal feed and auxiliaries. Special attention was also called to the motor driven centrifugal pump now supplied on the de-concentrator, when applied to high pressure work.

In exhibiting full size commercial types of its combustion control equipment as applied to the control of a small gas-fired boiler, Smoot Engineering Corp. called attention to the action of its new graduated excess pressure regulator for use on boiler feed lines, which varies the excess pressure in proportion to the square of the rating of the boiler in order to get the same water level for different ratings.

Of particular interest in control equipment, was the display of the dual thermostat by Johnson Service Co. This thermostat, which is of the pneumatic type, allows variation in temperatures to be made in various parts of the same building so that rooms that are not being used can be kept at lower temperatures than used rooms, at the same time maintaining true temperature regulation in both cases at once.

The Leeds & Northrup Co., in exhibiting its new combustion control equipment, showed how this control is based on an electric current which varies directly with the load on the boilers, this current being equally divided among the active boilers. At each boiler air flow and fuel feed are held in constant ratio to this control current. This company also showed the new Selsin remote indicator attachments with 24-in. dials, designed to be applied to any of its recorders.

Steam Turbines and Other Prime Movers

Elliott Co., in an attractive exhibit, showed a complete 100-kw. geared turbo-generator set, consisting of a Kerr steam turbine, a reduction gear and a Ridgway generator. The casing was open to show the construction of turbine wheels, the governor mechanism and the bearing arrangement.

The Terry Steam Turbine Co. featured the rotor of a multi-stage 500-kw. steam turbine, built in sizes up to 2000 hp. for high pressure or mixed pressure work, and also for bleeding. The unit shown was for 200 lb. operating at 3600 r.p.m. These units can exhaust or bleed up to 100 lb. or more. A steel case, pedestal bearing, auxiliary drive turbine, of 200 hp. capacity, was also shown, designed for 450 lb. throttle pressure and 2 lb. back pressure at 300 r.p.m. A 120-hp. non-condensing turbine was also shown, the feature being the one-piece wheel machined from a single forging.

Moore Steam Turbine Corp. called particular attention to its turbine oil relay governor, mounted so that it could be motor operated entirely independent of a turbine. A small movement of the governor actuates the mechanism positively by oil pressure, controlled by

a pilot valve, and a floating lever prevents hunting. There was also shown a four-stage, double-suction, 4-in. boiler feed pump, driven by a 7-stage steam turbine.

Westinghouse Elec. and Mfg. Co. showed several interesting types of steam turbine. The largest of these was a 150-kw. geared unit for mechanical or generator drives. In this unit the gear and turbine are in the same casing with only four bearings instead of six, the turbine wheel being overhung on the end of the pinion shaft. An oil governor is used, the impeller for it being on the end of the pinion shaft, and delivering oil at 60 lb. pressure to a piston in the steam chest. Oil from the governor system is also furnished to the bearings at 5 lb. through an ejector. The restraining ring and the safety pin on the turbine wheel were shown. This unit is also equipped with an external oil cooler and an auxiliary steam-driven reciprocating pump for the governor, which is thrown in automatically if necessary. A type 2-A M D steam turbine of 85-hp. capacity was also featured, showing the two reversing chambers, giving the effect of three stages in a single rotor. Attention was called to the single oil ring, the labyrinth and water-sealed glands, the construction of shrouding by which blades are fastened in groups of six or seven and welded. This unit has its support entirely at the center line so that it is free to expand and contract in all directions and is equipped with a centrifugal governor. A 7.5-kw., direct-connected turbo-generator set, of the same general blade construction as the 2-A M D unit, was shown, designed for 125 or 250 v., 4000 r.p.m. and 5, 7½, 10 and 15 kw. A model of the new Westinghouse side retort underfeed stoker was also shown. This is designed for wide range of speed for fluctuating loads and for furnaces that are too narrow to accommodate a center retort stoker wide enough to give sufficient fuel travel between the retort and the dump grate.

FIGS. 16-21. VARIOUS TYPES OF VALVES SHOWED DEVELOPMENT TO MEET HIGH PRESSURE AND TEMPERATURE CONDITIONS

The D. E. Whiton Machine Co. called attention to its Lee steam turbine for boiler feeding, equipped with a constant excess pressure governor, designed to maintain a constant excess boiler feed water pressure over the boiler pressure regardless of the latter quantity or of the quantity of water being pumped.

Standard Turbine Corp. featured its new direct-current, 125-v., turbine-driven lighting sets in capacities up to 10 kw. It also showed a four-stage turbine, calling attention to the discs made from rolled forgings, the exhaust end bearing and the steam end bearing designed to take care of expansion, the ball bearing governor and the one-piece valve bushings and seats.

The new four-cylinder Diesel engine generating set in the 36-kw. size was featured by Fairbanks, Morse & Co. This is designed for 650 r.p.m. and will be furnished in one, two, three and four cylinders, for 10, 20, 30 and 40 hp. respectively. Cylinders are cast in block, the solid injection principle is used, and a built-in compressor is a feature. It was originally developed for marine work. In addition to its standard line of ball bearing motors, this company also showed a double squirrel-cage motor, equipped with two independent rotors for across the line starting, together with a line of non-brush-lighting, single-phase, sleeve bearing motors.

Sterling Engine Co. displayed an 1800-hp. gasoline engine and a 225-hp. engine, both designed to operate at 1200 r.p.m. for driving pumps, generators and the like. A crankshaft from this type of engine was shown to illustrate the dynamic balancing which permits this high speed.

Centrifugal and Reciprocating Pumps

Nash Engr. Co. displayed single-stage, 3600-r.p.m. centrifugal pumps of 40 to 50 g.p.m. capacity for pressures up to 100 lb. for general pumping service. Of special interest was a vacuum pump for use on flat boxes of paper mills, a separate pump handling white water, an air pump taking off the air and the whole being driven by a synchronous motor, the three rotors being on one shaft. Small centrifugal compressors of 200 c.f.m. capacity for pressures up to 20 lb. were also shown.

Bethlehem Steel Co. showed a Weir turbine-driven boiler feed pump, built in capacities up to 90,000 gal. per hr.

Buffalo Forge Co. called attention to its new type S F single-stage pump shown in a 3-in. model. This is designed for motor or turbine drive up to 3600 r.p.m. and for heads as high as 500 lb., and is of the double-suction type. It also had a 2-in., class C H, single-stage centrifugal pump for general service.

The American nonclogging centrifugal pump, designed to handle water containing any mineral, animal or vegetable matter, or to handle sewage, was shown by the American Well Works.

Warren Steam Pump Co., in addition to various types of its recent double-suction centrifugal pump, called special attention to a condenser circulating water pump runner of the Francis type. This was originally designed for marine work and the runner was of compact design. This particular unit was designed for an 18-in. discharge, 600-r.p.m., 9000-g.p.m. and 26-ft. head.

The Frederick Iron & Steel Co. exhibited double-suction, single-stage centrifugal pumps and a three-stage centrifugal pump. A 1-in. house pump was shown for 30 g.p.m., 35-ft. head, 1750 r.p.m., driven by a ¾-hp. motor. Information was also given on the Frederick separator, of the revolving roll type, for grading coal and coke. In this separator the material, agitated by the revolving rolls, flows lengthwise over them, and all pieces small enough to pass between the rolls are removed.

Manistee Iron Works Co. called attention to an 8-stage Roturbo pump, designed for 750 g.p.m. and operating at 1750 r.p.m. against 1000 lb., and at 2300 r.p.m. against 750 lb.

The principal feature of the exhibit of Worthington Pump & Machinery Corp. was a type TS high-pressure boiler feed pump, one of three supplied to the Waukegan Generating Co. This is a 4-in., 8-stage unit, designed for 600 g.p.m. against 830 lb., handling water at 260 deg. and consuming 500 hp. This pump is made in two types, the type T—S having single suction with diffusion vanes, the type H—B having a volute casing, single suction, with no diffusion vanes. A bronze casing is used and hydraulic balance is secured by the disc and drum method. Another feature of the exhibit was the Axiflo sump pump, set up to show the motor thrust bearing, carrying the total thrust of the unit, the stuffing box to prevent oil leakage and the axial flow impellor of the open type, designed to eliminate close clearances and wearing rings. New pumps, of the single-stage, double-suction, ballbearing type, with horizontal split casing, were shown for heads up to 250 ft. at 500 g.p.m. and 3600 r.p.m. The R, S and V series of the same type are made in smaller sizes down to 65 g.p.m. at 160 ft. head.

Electrical Equipment

Some new and interesting types of motors and motor control were shown by General Electric Co., especially adapted for industrial work. Among these were a magnetic switch, type CR 7006 D4, equipped with temperature relays, and push button control. Also a compensator, with temperature load relays and accelerating relays. A new type CR 1034 high-voltage compensator was shown, having in addition to the temperature and accelerating relays, a time delay drop out feature and an extremely high rupturing capacity. The feature of the exhibit, however, was the centrifugal G-E air compressor, designed for motor or turbine drive, and built in sizes from 250 to 75,000 c.f.m. This compressor is designed to give a constant pressure over a wide variation in volume, with low power consumption and a steady, even flow of air, free from pulsations.

Improvements have also been made in the G-E electric-type flow meter. The instruments are now compensated for voltage variation, thus eliminating the need for a voltage regulator with the meter. On the meter itself, a welded steel body has been provided, designed for 600 lb. pressure.

The Cutter Electrical & Mfg. Co. exhibited a 4000-amp. ITE carbon circuit breaker of 3-pole design, for 440 v. a.c. with a solenoid closing mechanism for remote control. A 3000-amp. toggle switch, of the single-pole type, for 250-v. d.c. service was also shown, together with a 250-v., d.c., 800-amp. field discharge switch. A number of U-Re-Lites were exhibited, the most interesting one being a type L.L. 1000-amp. unit.

Allis-Chalmers Mfg. Co. featured a new enclosed self-ventilating motor, running in a cabinet full of dust, to show how it excludes dirt, dust, drippings and splashings under difficult industrial conditions. This motor was equipped with Timken roller bearings. Other items

of particular interest were the Reyrolle armor-clad switch gear, and various applications of the Texrope drive.

Piping, Valves and Valve Control Equipment

The Chapman Valve Mfg. Co. featured a large motor-operated valve of chrome nickel steel, designed of square and round-cornered Van Stone joints and examples of pipe swedging.

Yarway Type C tandem blowoff valves, a recently-developed type, with the lower packing ring protected, were exhibited by Yarnall-Waring Co. These valves are made for service from 750 to 1200 lb. Of particular interest also, was the improvement made in the hump

FIGS. 22-27. SMALL TURBINES, PUMPS, CONDENSERS AND THEIR ACCESSORIES AND A NEW REFRIGERATING MACHINE WERE FEATURED

for working pressures of 600 lb. and total temperatures of 750 deg. The company is also making 900-lb. valves to withstand total temperatures of 1200 deg. As a result of research work carried on by the company, data have been obtained on causes of bolt failures under severe conditions.

An Atwood 6-in., 600 lb. gate valve with a Liberty valve operator equipped with a safety clutch was featured by Pittsburgh Valve, Foundry & Construction Co. An interesting exhibit was also made of pipe fabricating work for 400-lb. service. This exhibit showed the Atwood line weld, the Atwood interlock neck, examples fittings of the company's involute spray nozzle for spray ponds.

At the booth of the Edward Valve & Mfg. Co. was shown the new offset valve, designed for 600 and 900-lb. work, according to the standards of the A.E.S.C. This design provides for equal sections of metal throughout the body of the valve, to equalize the expansion and contraction strains. The inlet and outlet passages are offset, thus conducting the expansion stresses of the pipe line and valve on lines passing above and below the valve seat.

The Lunkenheimer Co. exhibited a 6-in. horizontal

swing check valve of cast steel with monel metal mountings, designed for 400, 600 and 900-lb. service. Also a 10-in., motor-operated gate valve for the same pressures, equipped with a bypass.

G. M. Davis Regulator Co. displayed a wing disc nonreturn valve for turbine bleeder lines, air and gas lines, condenser outboard lines and so on, made in sizes from 6 in. to 42 in. inclusive. This is designed to be noiseless, to eliminate pressure drop across the valve, to have greater port area, and is of the multiple spring type with stainless springs.

The Wonder portable pipe bending machine, designed to bend cold pipe without filling it with any substance, was exhibited by the American Pipe Bending Machine Co., Inc. These machines are both hand and motor-operated and can be furnished to bend pipe in sizes up to 20 in.

Coffin Valve Co., in exhibiting the Dow disc arm pivot valve, used as a check valve in pump discharge lines, called attention to the operation by hydraulic cylinder, which prevents slamming. In exhibiting an 8-in., motor-driven gate valve, actuated by the Kelty drive, attention was called to the clutch, which is of the series parallel multiple disc type, inserted between the motor and the valve. A centrifugal switch gives overload protection and also acts as a limit switch in the closing of the valve.

A new type of solenoid-operated safety valve, for pressures up to 1200 lb., was shown by Manning, Maxwell & Moore, Inc. This valve was controlled by the Ashcroft pressure control system and incorporates a pilot valve actuated by the control which in turn actuates the main valve.

National Tube Co. exhibited pipe coils, Van Stone joints, pipe bends designed to show the ductility and toughness of the metal. It also had a working model showing the welding scale-free process as applied on butt-welded pipe, in sizes from 3 in. down. There was also shown pipe from ⅛ in. to 96 in., using the lap weld from 4 in. to 20 in.; however, this company can make lap welded pipe down to an inch and a quarter. Hammer welded pipe was shown from 20 in. to 96 in.

Framanco forged steel pipe fittings were featured by Continental Valve & Equipment Co. The octagon ends of these fittings were especially noted, as these are designed to add strength to permit the use of a flat-faced wrench and to prevent tearing of the corners.

Everlasting Valve Co. called especial attention to the new boiler draw-off Wylie-Wilson process. In this process a closed drawoff tank suitable for full boiler pressure is interposed between the boiler blow-off valve and the discharge valve to sewer. The blow-off water withdrawn from the boiler passes into the drawoff tank and, when a predetermined amount of water has been drawn off at a predetermined velocity of flow, the discharge from the boiler automatically ceases. The water is then withdrawn from the tank, preferably not at boiler pressure but at greatly reduced pressure. The company also exhibited the new duplex blowoff unit, consisting of an Everlasting valve, followed by an angle valve of special construction.

Jenkins Bros. showed its new rapid action valve for industrial service, made to be opened by a short pull of a lever and to remain open automatically. This is made for service up to 200 lb. The Jenkins modulating valve for radiators was shown, having the disc and seat in a vertical plane, thus preventing trouble from scale and condensation.

Foster Engineering Co. called attention to a new special chrome mixture, which forms a new metal for use in valve construction.

A pilot-operated hydraulic valve was featured by Homestead Valve Mfg. Co., together with the standard types of Homestead valves for pressures up to 3000 lb.

An interesting header exhibited by Pittsburgh Piping & Equipment Co. was made of 10-in., extra heavy pipe. One end was swedged to 8 in., with a rolled flange screwed on and welded; the header also had one 10-in., rolled steel Van Stone flange, one 6-in., American patent-welded neck, with rolled Sargol flange, and one 4-in., butt-welded neck with rolled steel male and female Van Stone flange.

The Wm. Powell Co. showed a 6-in., motor-operated valve of steel for 400-lb. superheated steam service. The Powell No. 2 clean cup was shown. This is a grease cup with an Alemite fitting for refilling the cup, which is automatic in its action.

E. B. Badger & Sons Co. exhibited 8-in. Badger expansion joints of the self-equalizing type, equipped with monel sleeves for high temperature. Another form of this unit is made double and can be furnished with nipples to allow welding into the line.

Walworth Co. featured a 12-in., 400-lb. gate valve with motor drive to call attention to the ball bearing yoke and other construction features. An actual working model of the testing machine used to apply a 125-lb. air test under water to all Kewanee unions was set up. Sixteen different valves of various types were shown entirely disassembled.

Henry Vogt Machine Co. exhibited its full line of drop forged steel valves and fittings for steam or hydraulic pressures up to 10,000 lb. on the fittings, and 6000 on valves. The valves made for 900-lb. work are designed for a total temperature of 1000 deg. F.

The Dean Swingate valve is a recent development of Payne Dean, Ltd. This valve is designed in such a way that pressure keeps the seats, packing and bonnet tight and pressure and velocity close the valve. A grinding gear is a feature of this valve and it is designed for small head room. Two of these valves were exhibited in the 8-in. size, one designed for air motor control and for a closing time of 2½ sec., the other designed for electrical operation. An interesting station load indicator, consisting of a projection apparatus by which the figures can be thrown on a screen in any size, was also featured by this company.

Chas. Cory & Son, Inc., featured especially its seamless metal hose for steam, gas and oil. This can be supplied for pressures as high as 10,000 lb. and has had extensive application for Diesel engine exhaust and for steam-jacketed hose. For heavy duty service, it is used inside the interlocking metal hose that this company has previously made.

Midwest Piping & Supply Co. exhibited a 4-in. pipe with a Midwest joint deflected 3 deg. and held under 1200 lb. pressure. It also showed how its process for rolling of flanges gives a flange thickness greater than that of the original wall and how rolling improves the crystal structure. It also exhibited samples of the Van Stoning of wrought iron pipe.

Steam and Vacuum Traps

Bundy Steam Trap Co. exhibited a new ½-in. trap, designed for feeding small boilers and incorporating the same features of design as are used in its larger units. These include the ground joints at trunnion and elbow connections, knife edge bearings, monel valve seats and discs and other features.

Sarco Co., Inc., called attention to its new heavy service and blast trap No. 9-3 for vento coils and the like. These are supplied in capacities from 1000 to 2000 lb. per hr., designed to handle from 3000 to 6000 sq. ft. of direct radiation. The Sarco packless inlet valves were also shown.

Armstrong Machine Works exhibited a new compound trap for handling large volumes of water under high pressure. These traps are fitted with piston-actuated valves which handle the major flow of water, although the upper valve is also wide open and discharges a large amount.

The great mystery announced by Wright-Austin Co. was solved by the discovery at its booth of the new Wright-Austin bucket trap, a prize of $200 cash being offered for a name for this trap. It has a special regrinding valve, large capacity at pressures up to 400 lb. per sq. in., automatic air discharge feature, monel metal valves and seats and straight line connections. Another feature was the water gage for 400-lb. service. This is made with a forged body, nickel steel floats tested to 1200-lb., high and low water alarms and double arm trycocks.

Warren, Webster & Co., in a complete working setup of a heating system, featured its Series 78 thermostatic trap, class 2, for pressures to 50 lb., and class 3, to 100 lb.

In the Nicholson supertrap, featured by W. H. Nicholson & Co., a large discharge valve is operated by a steam piston. This company also exhibited its flexible coupling, consisting of two cast steel hubs, keyed to their respective shafts with dovetail slots to receive floating keys which connect them.

Kieley & Mueller, Inc., displayed a low-pressure return trap and air eliminator for use on vapor heating systems.

Feed Water Control, Regulators

Mercon Regulator Co. had on exhibit one of the largest pump regulators in existence, built for use in the plant of a large public service company, and designed for 630-lb. steam pressure, 780-lb. water pressure and a capacity of 900 g.p.m. This company also demonstrated by diagrams and charts its new arrangement of the Mercon Regulator, installed on the downstream side of a water level controller.

The Fisher Governor Co., Inc., called attention to its new electric float switch, suitable for various types of work for pressures up to 400 lb. and for high temperatures. In this switch a ball float actuates a snap switch which in turn controls a valve, a bell or any other desired equipment. On the type 235 liquid level controller, also shown here, a new type of pilot valve has been provided. This arrangement permits remote control by the float up to 200 ft. Another item shown was the gas governor for gas-fired boilers. This regulates boiler pressure by regulating the flow of gas to the burners.

On the type S differential pressure regulating valve, shown by the S-C Regulator Mfg. Co., a new model was shown, designed to give variable differential excess pressure for boiler feeding. A drainage control, designed to prevent air-binding, was also featured, and a model of the high pressure boiler feed pump governor for service up to 1000 lb. pressure was shown to illustrate the design without stuffing boxes.

Mason Regulator Co. featured a new reducing valve, No. 192, designed specially for district heating service. This valve is provided with a bypass in the body and is designed to shut off automatically if the pressure fails on the low-pressure side, as in the case of a pipe or radiator breakage. On the No. 130 hydraulic regulator, attention was called to the ball bearing rolling weights.

Specially featured by Ruggles-Klingemann Mfg. Co., was the General Electric controller panel, actuated by an R-K differential pressure controller, mounted on the rear of the panel, as applied to boiler feed service. The dual motor, step action, hydraulic regulator was also featured in a working model, the motors being both compensated for live steam and process work. The live and exhaust steam valves were interlocked in such a way that the maximum amount of exhaust steam would be used at all times.

The exhibit of Northern Equipment Co. featured a working model of the Copes boiler feed water regulator, showing the relation between boiler load, water level and automatic control of water input. A water level indicator was shown based on the balancing of a constant head of water against the varying head of water caused by fluctuations in water level in the boiler.

Atlas Valve Co. displayed its new Campbell boiler feed regulator, employing the principle of pressure drop through an orifice. The variations of water level are measured by variations in steam pressure, the steam coming from the water column as the water level falls below the bottom of a pipe inserted vertically from the top of the column. These variations of pressure are transmitted through a diaphragm to the control valve.

Oil and Water Purifiers and Coolers

Attention was called by Griscom-Russell Co. to a section of its bent tube, high-pressure evaporator, of the submerged self-scaling type. The headers in this unit are arranged vertically and held rigidly at top and bottom, so that the bending of the tubes, due to change in temperature, cracks off any scale which may form.

Cochrane Corp. featured the Cochrane strainerless conical filter, designed to eliminate the use of collecting manifolds and strainer heads. A single control valve is provided, which gives complete control of back washing, filtering and all other operations, while a flow-rate controller is provided to prevent washing out of the sand.

Boilers, Economizers, Superheaters, Water and Oil Heaters

The Dampney Co. of America, by means of an illuminated diagram, showed the method of application and the action of Apexior, a protective coating for the internal surfaces of boiler drums and tubes. This material, which is a liquid of about the consistency of paint,

comes all prepared for use, is injected into the tube by means of a depositor, and is then brushed onto the tube surface by means of a powercoater, used in place of the cutting head of any standard type of tube cleaner.

Connery & Co., Inc., showed a new type of adjustable covering support for its wagon top boiler breechings. The new support consists simply of a series of brackets fastened to the breeching with arms reaching

FIGS. 28-33. REFRACTORIES AND INSULATING MATERIAL SHOWED INFLUENCE OF TRENDS TOWARD HIGHER TEMPERATURES

out and carrying a series of holes through which the rods are run, thus allowing adjustment to give whatever space is considered necessary under the covering.

The Superheater Co. exhibited units taken from superheaters after long service at Hellgate and at the Fordson plant. The unit from the Hellgate superheater was in service from November, 1921 to December, 1925, and during that time handled approximately 32,000,000 lb. of steam with gas temperatures at the superheater of 1200 to 1500 deg. The Fordson unit was in use from September, 1920 to December, 1925, and handled about 40,000,000 lb. of steam with gas at 1500 to 1800 deg.

A new and interesting type of electric steam generator was shown by the Bigelow Co., developed in cooperation with the General Electric Co. The boiler unit itself is designed for 100-lb. working pressure in accordance with the A. S. M. E. boiler code requirements. The small units, in sizes of 12, 24 and 60 kw., are built with the heating elements inserted from the bottom. The large units in sizes up to 250 kw. are of the double-cylinder type. The standard Bigelow Hornsby boiler was also shown by an actual working model.

Babcock & Wilcox Co. displayed a high-pressure water gage of the flat type, as applied to many modern high-pressure boilers, also several forged steel nozzles, wrought steel headers of various types and an industrial motion picture showing steps in the building of B. & W. boilers.

A new water wall construction was featured by Heine Boiler Co. for pressures of 600 to 700 lb. This has headers of square seamless tubing forged to round on the end for Van Stone flanges, with special type of hand hole plates opposite each tube. The ends of the headers are also closed by forging. Drawings and photographs were shown of a 415-lb., V-type bent tube boiler and of a one-piece drum with the longitudinal seam welded before the butt strap is put on.

The Wickes Boiler Co. showed a patented one-joint header designed to take the rivets out of the fire and to eliminate wrapper sheets used sometimes on box header types of water tube boilers.

Boiler Engineering Co. showed a section of the Beco baffle wall illustrating the self-supporting feature of the walls and the reduction in weight obtained by the design.

Lamont Steam Generators, utilizing the principle of film evaporation, attracted considerable attention at the booth of the Lamont Corp. In this boiler extremely small tubes are used, a large quantity of water is injected into each tube, the water forms a film on the tube and steam forms in the hollow core, and the water and steam are then removed and separated.

Meters, Thermometers and Other Instruments

Republic Flow Meters Co. exhibited its new line of panels for measuring and controlling flow of steam, water, gases and the like. Various combinations of indicating and recording meters are mounted on panels according to the particular records desired for control of boilers, gas producers, both individual and totalizing, panels for water pumping plants and filtration plants, and so on. Improvements have been made in the flow integrator. The panels exhibited were also equipped with a new type of recorder, using a strip chart on which six records can be placed. The CO_2 recorder has been equipped with electrical transmission to the indicator or recording device from the machine itself.

A new steam pressure indicator, known as Model 11, was the feature of the Bristol Co.'s display. This indicator is designed with an unusually wide scale, which can be read easily at a distance and the unit is designed as the receiver for the long distance transmitting pressure gages.

The Brown Instrument Co. had on exhibition a large display panel to show how the inductance bridge principle is applied in its new electric flow meter. Variations in voltage are of no consequence, since the proportions of voltage and magnetic flux, in the divided coils, will be the same, no matter what the actual voltage is at the meter. The Brown CO_2 recorder has been improved by placing the condenser, filter and cell together as a single unit which is water-cooled. Use of a storage battery with the recorder has been eliminated by providing a motor generator set.

The Ashton Valve Co. featured a new 48-in. master pilot gage for the boiler room, equipped with a Universal dial. This dial, instead of showing boiler pressure, shows variations from the standard pressure.

At the booth of Bailey Meter Co. was shown a most interesting and attractive exhibit of glass fittings to demonstrate the effect of pipe fittings on flow of fluids. A long 3-in. glass pipe was equipped with a Bailey fluid meter, the whole arrangement designed to show the orifice, the differential pressures at various points, the vena contracta and the restoration of pressure. Water circulated through this tube, passed around through a standard pipe fitting, and then through another glass tube where the wave disturbance caused by the fitting was clearly shown.

At the booth of C. J. Tagliabue Mfg. Co. was shown the new model of the Tag Mono duplex recorder, indicating both CO and CO_2 in flue gas, and recording both on a 24-hr. circular chart. On the indicator of this instrument, two pointers are used, a red one and a black one. When the red pointer shows, combustible gases are present, but when no combustible gases are present, that is, when there is no CO, the red pointer is covered by the black one, thus indicating the best combustion conditions at that particular time. One of the features of the apparatus is the centralized alkali supply distributed by a motor-driven centrifugal pump at the alkali tank. All parts of the instrument are of metal to make the whole device rugged and dependable and eliminate glassware.

The Foxboro Co., Inc., demonstrated a new rate-of-flow controller, in which the fluid is measured and controlled by the new Foxboro differential recorder. A new boiler water level recorder was exhibited, which indicates high and low water, blow down and priming.

A newly developed control system was shown by Uehling Instrument Co. which is adaptable to control of temperature, pressure, vacuum, combustion, humidity or any other variable. This is not a stock apparatus but has been applied to many special types of work. Its operation depends on the action of a newly-developed electrical relay, actuated by any of the variables it is desired to control.

A Reliance gage column, designed for 650-lb. pressure, and tested for 1500 lb., was featured at the Paul B. Huyette Co. booth. This has seamless copper nickeled floats, a flat type gage glass of ⅝ ground glass, separate high and low water alarms renewable outside the column and specially designed gage columns. The P.B.H. adapter, for converting a vertical water gage to an inclined one, was shown as well as a complete line of the new Hays pointer-type gages.

A nozzle-type safety valve for 1500-lb. service was displayed by Crosby Steam Gage and Valve Co.

Weston Electrical Instrument Corp. showed a complete display of its rectangular space-saving meters, calling particular attention to the junior portable instruments with bakelite casings, designed for light weight, for industrial work and field surveys. A newly-developed magneto, which was run for 1715 days at 2000 r.p.m. with 0.4 per cent speed variation, was also shown suitable for adaptation to speed-measuring instruments.

Features of the long distance recording thermometer shown by Taylor Instrument Cos. were the electrical transmission, the instrument unaffected by voltage variations, the operation of the meter unaffected by vibration, the high torque to overcome friction errors, use at any distance, and compensation for stray magnetic fields.

At the booth of Diamond Power Specialty Co. was shown a Dialoy element which has been used for 302 days in the first pass of a boiler at Hellgate Station.

The Vulcan Soot Cleaner Co. called attention to the

improved construction of the packing gland, allowing greater ease in packing. Another air valve has also been added on this unit to insure complete breaking of the vacuum.

The Bayer Co., in exhibiting a special attachment to its valve-in-head model K-2 soot blowers, showed how air is circulated through the blower element when it is not in use.

hauster. They are supplied for pressures up to 6 lb. per sq. in. and in sizes up to 600 c.f.m., and are applicable, of course, to many other processes. The new Buffalo Hi-pressure unit heaters were also exhibited. These are suitable for steam pressures up to 150 lb. and use the Buffalo conoidal fan.

Clarage Fan Co. featured its type FD blower designed for high speed forced draft work. This has two

FIGS. 34-38. PNEUMATIC SWEEPING SYSTEMS, EVAPORATORS, SUPERHEATERS, ASH-HANDLING AND MECHANICAL EQUIPMENT

DRAFT EQUIPMENT, FANS, BLOWERS, ETC.

L. J. Wing Mfg. Co. featured the Wing Featherweight unit heater for industrial use, designed to be installed overhead and to direct the heat downward to the floor or working level.

The new Buffalo cinder-eliminating fan was announced by Buffalo Forge Co. The rotor of this fan is identical with that used in the Conoidal fan and the front part of the casing contains a special scroll designed to eliminate any solids in the gas and discharge them through louvres into an air-tight hopper. There was also shown the Buffalo multi-stage blower and exsingle inlet wheels with 16 blades each pitched backward from the direction of air flow and ribbed to prevent distortion. Ball bearings are used throughout, the bearing supports being on pedestals outside the housing, which is of extremely rugged construction.

The Sturtevant Turbo-vane fan has now been adapted to induced draft service by B. F. Sturtevant Co. This has a bladed impeller with curved floats designed to be self-cleaning, operates at high speed, has water-cooled bearings and symmetrical housing with spiral inlets. The most recent development of this company, however, is the propeller fan for forced draft

work. This is a unit designed to supply volumes up to 40,000 c.f.m. at 5-in. static pressure. Another recent development shown at this booth, was the Sturtevant tubular air heater, made in standard sections five tubes wide and any number of rows up to about 36. A stuffing box arrangement around the movable tube sheet is designed to prevent leakage.

Gratings and Stairways

Irving Iron Works Co., in its display of Subway grating, called attention to the Visabledge Safstep which has a special double crimp near the nose of the step, thus helping a person using the stairs to see the edge of the step clearly. Another feature of construction on the Subway grating was the streamline splice by which the grating is made into one continuous and rigid platform over its whole area.

Feralun, an antislip platform material and stair tread, was featured by American Abrasive Metals Co. This is made of cast iron with an aluminum oxide abrasive cast in the wearing surface. It is designed to be effective when there is any slippery material on it. It is made in floor plates, trench covers, drainage types and stairways, as may be desired.

The Trilock Co. also exhibited a grating and tread, the bars of which are locked by a right and left twist lock in alternate bars, and the cross-bars are pressed under 1600-t. hydraulic pressure into the two twist locks.

Keystone Lubricating Co. showed an interesting model of a rolling mill, lubricated with its Keystone Safety Lubricating System. This showed the device for putting the whole lubricating system under a pressure of 150 to 200 lb., the converter cup for equalizing pressures, and the quick release regulating valve on each bearing.

Condensers

Of particular interest, at the booth of the Wheeler Condenser & Engr. Co., was a model of a surface condenser, equipped with special valves for reversing the water flow to clean the condenser. One water inlet and one water outlet are provided on each water box, and motor-operated flap valves are built into the water boxes so that the water from either pump can be diverted into either half of the condenser.

C. H. Wheeler Mfg. Co. called attention to a new three-stage, high vacuum Radojet air pump. A dead end test on this pump showed vacuum of 29.96 in. of mercury compared to a 30-in. barometer and the unit operated at 29.85 in. of mercury with the same barometer, removing 38 lb. of air per hr. with cooling water at 70 deg. This company also featured a twin drainage control for removing condensate from the inter and after condensers of Radojet air pumps.

Ingersoll-Rand Co. showed an illuminated drawing of its new type of single-pass surface condenser. This showed the heart-shaped shell, the staging of tubes and flow areas proportionate to the steam volume and the way in which the condenser is divided into sections by steam-tight support plates. There was also exhibited here a 350-g.p.m. Cameron multi-stage centrifugal boiler pump, designed for 3500 r.p.m. and 900 lb. pressure, as supplied with four other similar units to the new plant of the Solvay Process Co.

Coal and Ash Handling Machinery

At the booth of the Allen-Sherman-Hoff Co. was a Scene-in-action showing the operation of the Hydrojet system for the handling of ash. This interesting view showed the accumulation of ash in the air-cooled, sectional cast iron furnace bottom, the type C gate, controlling the flow of ash which dropped to the cast iron clinker chamber. From this chamber it is fed hydraulically through a grid into the Hydrojet sluiceway.

A quarter-size model of the American Ring coal crusher was shown at the booth of American Pulverizer Co., showing the method of crushing run of mine coal to any desired product as ready feed for coal pulverizers. This machine will crush coal down to ¼ in., tramp iron being thrown out automatically and an automatic apron preventing overloading and acting as a safety valve on the machine.

The standard line of steam jet and hydraulic conveyors of the Girtanner Engineering Corp. was shown by working models. The construction of 90-deg. elbows with liners and nozzles was shown and the models were arranged to duplicate actual plant conditions.

In its complete working model of a centralized coal and ash handling system, R. H. Beaumont Co. incorporated a tram car with an automatically opening bottom to carry the coal from the skip hoist across the bunkers instead of using a conveyor.

Another interesting coal handling model was shown by Richardson Scale Co., showing a miniature boiler house with three types of automatic scales and larry, weighing coal to tiny stokers and miniature pulverizers.

A telescopic hoist for handling ash cans, as applied to ash removal systems under sidewalks, in capacities up to 500 lb. load, was featured by Gillis & Geoghegan.

Sauerman Bros., Inc., showed a small model of its drag scraper as used to store and reclaim coal. All controls are from a central point, the tail block car being propelled around its track by an electric motor and the scraper itself being of extremely rugged construction.

Cleaning Equipment

Tabco products and systems for pneumatic sweeping of power plants were featured by Allen & Billmyre Co., Inc. These were shown in operation picking up large wads of paper, nuts, washers and other unusual materials and are designed for removal of coal siftings, pulverized coal dust and such materials in power plants. A 5-hp. blower exhauster was in operation to show its quiet running and to call attention to the fact that it has only one moving part.

The Spencer Turbine Co. showed its type of vacuum cleaners for industrial plants, together with Spencer turbo-compressors for supplying air at one to three pounds pressure.

Air Conditioning Equipment

An interesting model of a power house, equipped with Swartwout ventilators, was exhibited by the Swartwout Co., showing how, with proper inlets at the floor level and the windows closed, these rotary ventilators will produce a steady air flow through the room.

Carrier Engineering Co. showed a full-size model of its new Dielene refrigerating unit and an opened model of the centrifugal compressor used with this unit, showing how the only contact of moving parts is at the

bearing. An attractive illuminated drawing also showed the application of this unit to air conditioning in a theatre to cool and humidify the air.

The American Blower Air Filter, with its cell construction, was demonstrated by American Blower Co. Each of these cells is composed of perforated aluminum plates on which filaments are placed to catch the dirt, filter of two-stage construction with renewable oil pad at the top of each filter cell. The National rotary air filter and the Phoenix constant effect air filter, both of the moving screen type, were displayed by Drying Systems, Inc.

Ernst & Co. featured its forged steel water column for service up to 750 lb., equipped with the adjustable

FIGS. 39-45. UNIT PULVERIZERS, COMBUSTION CONTROLS, TURBINES, DIESEL ENGINES AND PUMPS

the perforation of the plates being staggered. This is designed to keep the dust elimination constant, to avoid the use of adhesives and to provide a simple mechanical design.

The Reed Air Filter Co. displayed the Reed Self Cleaning filter in which the oil and dirt are washed from the tubes as soon as the fan is shut down, thus making it possible to clean the unit thoroughly. The Cooling Tower Co., Inc., displayed the Tangldust air inclined water gage, flanged steel fittings and the National water column illuminator, together with leakless gage cocks. National Co. displayed a line of cell door hardware for compartment doors such as those used in indoor bus structures in power plants.

Andale Engineering Co., among its various types of strainers, oil coolers and similar equipment, featured the bronze tube air cooler for cooling, drying and cleaning compressed air. This unit has a bronze tube bundle,

removable as a unit, the air goes through the tubes and the unit is set vertical to occupy minimum space.

A new and interesting type of steam purifier was shown by International Filter Co. By causing the steam to pass between thin bands or ribbons, which give it an undulating motion, any liquid or solid particles will be deposited on these bands and projected into scrubber pockets at the side.

Ross Heater & Mfg. Co. showed a high-pressure evaporator designed for 1600-lb. pressure on the tube side, to be used with tube and tank cracking coils. The shell was machined from a solid forging and there are 16 passes through the tubes.

An interesting exhibit of mechanical speed reduction equipment was made by De Laval Steam Turbine Co. This showed a De Laval worm gear, driven from a motor, reducing the speed from 1150 to 159 r.p.m., then with a second similar worm gear unit, raising the speed to 1150 again to drive a generator to supply power for a pump testing outfit which was set up in the booth. A 350-hp. multi-stage turbine rotor, designed for 10,000 r.p.m., was also shown.

Timken Roller Bearing Co. displayed an apparatus for showing how the alinement of rollers in its bearings is automatically taken care of by the construction of the rollers and the cone and does not depend on the cage. This company also displayed a 9-in. roll neck bearing used in steel mills, and has supplied them up to 20-in. bore.

Several new and interesting lubricating devices were exhibited by Carr Fastener Co. The new Dot automatic cup, exhibited in operation on a revolving shaft, is filled with the Dot gun and feeds back grease under control by a tapered plug in an orifice, to prevent the grease rushing out when pressure is first applied. This construction is designed to give constant flow, the cup warms up with the bearing, feeding more lubricant as the bearing gets warmer and seals the end by keeping the bearing full. The Dot gun is filled through the nozzle from a tank; this allows the gun to be filled without removing plunger or cap.

The Klingerit Co., Inc., showed its new piston valve for high pressure or saturated steam or gases. This valve employs a piston instead of a disc, thus eliminating stuffing boxes and regrinding.

In showing the Liberty valve operator, Liberty Electric Corp. called especial attention to the magnetic clutch driving the valve stem through a multi-disc mechanical safety clutch set to slip before the torque transmitted to the stem becomes too great.

The Keystone slicing stoker, a hand-operated stoker equipped with slicing pins, which come up through the fuel bed to break up the fire when necessary, was exhibited in a full-size model.

News Notes

STANDARD TURBINE CORP., Scio, N. Y., announces the opening of an office at 1905 Chemical Bldg., St. Louis, Mo., under the management of F. E. Bausch.

J. P. GREENWOOD, who for the past year has been associated with McClave-Brooks Co., will return to Dallas, Tex., and engage in engineering on Jan. 1, 1927.

ANNOUNCEMENT has just been made that the Illinois Stoker Co. of Alton, Ill., has recently consolidated with the K-B Pulverizer Corp., New York. The Pulverburner is now being manufactured and sold by the Illinois Stoker Co.

THE WICKES BOILER CO., Saginaw, Mich., has recently appointed Henry E. Aldrich, general manager, with headquarters at Saginaw, Mich., and J. Robert Fortune as general sales manager with headquarters in the General Motors Building, Detroit, Mich.

PERKINS MACHINE & GEAR CO., Springfield, Mass., a new company incorporated under the laws of Massachusetts, has recently taken over the Perkins Appliance Company. The management of the new company is vested in Julian L. Perkins and J. A. Perkins, who organized and developed the old business with the addition of John Oakley, of the Baush Machine Tool Co., and Adolph W. Gilbert, president of Chapman Valve Mfg. Co., and his associates. Mr. Gilbert is also chairman of the board.

H. M. BYLLESBY & CO., Chicago, Ill., announces the purchase of the Midwest Public Service Co., supplying electricity to a group of twelve communities in Wyoming, southeastern Montana and southwestern South Dakota. The new properties will be operated as part of the Casper, Wyo., division of the Mountain States Power Co.

PAUL ACKERMAN has recently been appointed engineer of the service department of The Timken Roller Bearing Co., Canton, O. All service work of the automotive, industrial and steel mill divisions will be co-ordinated under his direction and he will maintain his headquarters at Canton, O.

ADOLPH J. LUICK, formerly valuation and rate engineer of the North American Light & Power Co., has become associated with Thomas J. Lucas under the firm name Lucas & Luick, consulting engineers with offices at 231 So. La Salle St., Chicago, Ill.

MEFFORD R. RUNYON, formerly connected with the Benson Rolling Mills, manufacturer of brass and bronze, has recently been appointed district sales manager for the New York Metropolitan district by the Bridgeport Brass Co., Bridgeport, Conn.

FLEXITALLIC GASKET CO., Camden, N. J., has established a branch office at 539 Singer Bldg., New York City, with Frank Groves, sales manager of the company, in personal charge.

THE CITIES SERVICE CO., operated by Henry L. Doherty & Co., New York City, has acquired the plant and property of the Bluff City Electric Co., Bluff City, Tenn., and will operate it in the future.

KIELEY & MUELLER, INC., New York City, announces the appointment of Rittelmeyer & Co., Bona Allen Bldg., Atlanta, Ga., as its representatives in that state.

PLANS ARE BEING completed for the proposed merger of a number of power companies in Georgia under the direction of the Georgia Power Co., Atlanta. Some of the companies to be included are the Mutual Light & Water Co., Brunswick; Southern Power Co., Atlanta; Athens Gas Light & Fuel Co., Athens.

The UNION CARBIDE & Carbon Corp. announces the election of W. F. Barrett to vice-presidency and G. W.

Mead to member of the board, which took place at a meeting of the board of directors on Nov. 23.

AMERICAN MACHINERY and vehicles valued at $17,400,000 were included in American shipments to the Soviet Union during the Soviet fiscal year ending September 30, according to figures compiled by the Russian Information Bureau. The total of American exports to the Soviet Union for the fiscal year was $55,000,000, so that machinery accounted for nearly one-third of the business.

THE MONTANA-DAKOTA POWER CO. has arranged for the purchase of the plant and property of the Medicine Lake Electric Utilities, Medicine Lake, Mont., and will take over and operate with its other state properties. Plans have been arranged for the construction of a high-tension transmission line to Medicine Lake, to furnish power to this section. Plans are also under way for the acquisition of the municipal electric power plant at Miles City, Mont., for a stated consideration of $300,000, and if acquired, extensive work will be carried out in this territory, including transmission line construction. The purchasing company was organized recently; C. J. Heskett is general manager.

THE NORTHWESTERN POWER & LIGHT CO., Port Angeles, Wash., has work in progress on a new hydro-electric plant on the Elwah River about 11 mi. from the city to be used primarily for service at the new local mill of the Washington Pulp & Paper Co. The plant will be of the single unit automatic type, the generating equipment comprising a 17,000-hp. vertical shaft water wheel driving a 13,333-kv.a., a.c. generator. The transformer station will be of the outdoor type, with three 4500-kv.a. transformers, switching equipment and auxiliary apparatus. A single arch dam has been built 190 ft. high, providing a reservoir to impound approximately 40,000 acre feet. It is expected to have the new station ready for service early in the coming year.

Catalog Notes

COMBUSTION ENGINEERING CORP., New York City, has recently issued a new bulletin describing Raymond roller mills as made by Raymond Brothers Impact Pulverizer Co., Chicago, Ill. In addition to describing the standard construction of the Raymond roller mill with air separation, in the various types of low and high side mills, the booklet calls attention to a new pneumatic feed control which has been applied to these mills. This control is operated entirely by the change in vacuum in the machine which, in turn, changes as the amount of load varies. The amount or quantity of material fed is varied by the speed of the feed roll, regulated by means of the simple pawl and ratchet mechanism and by the length of the crank arm. The pawl which engages the ratchet wheel has attached to it the pneumatic control for automatically lifting the pawl out of contact and dropping it into contact, depending on the variation of vacuum in the system. Interesting photographs of installations and of details of the Raymond mills are given in the bulletin.

IN CATALOG No. 51, just issued by Joseph A. Martocello & Co., Philadelphia, Pa., a complete and interesting discussion is given of the whole subject of raw water aerating equipment for ice making. The catalog, which contains 176 pages and many illustrations, discusses, first, the general principles of aerating with both the low pressure and high pressure systems and various arrangements of can baskets and drop tubes and then goes on to describe details of the equipment as made by this company.

Instructions for operating various types of raw water systems are given and particular attention is paid to the advantages of the use of low pressure air in producing high quality ice.

LINK-BELT CO., Chicago, has established a temporary branch office at 152 Temple St., New Haven, Conn., in charge of R. H. Hagner.

PHYSICAL PROPERTIES of Nickel and Nickel-Chromium Steels are told in No. 2 of the bulletins on nickel steel data and applications issued by The International Nickel Co., 67 Wall St., New York City.

THE WM. B. PIERCE CO., Buffalo, N. Y., in a small folder describes the improved Dean, which is a tube cleaner for water tube boilers and gives some fundamental information on the removal of scale from boilers.

PIONEER RUBBER MILLS, San Francisco, Calif., in a new 98-page illustrated catalog, describes its principal products, such as rubber belting for power transmission, conveyors, elevators and the like, hose of all kinds and packing.

THE HYDRAULIC PRESS, a new magazine published by the Hydraulic Press Mfg. Co., Columbus, Ohio, contains several interesting articles on applications of hydraulic presses and other hydraulic equipment in the manufacture of metal products, bakelite, storage batteries and other equipment.

AEROIL BURNER CO., INC., Union City, N. J., has recently issued bulletin No. 52 entitled "Winter Construction Tools" and bulletin No. 54, the subject of which is "Smokeless Heating Equipment." These bulletins are prepared to show the application of oil burners in the building and other industries where a portable oil burner is needed.

"THE RIGHT REFRACTORY FOR THE RIGHT PLACE" is the principal subject discussed in the December number of the bulletin issued by Laclede-Christy of St. Louis, Mo. In this bulletin the scope of the work carried on in the company's research laboratory is described in such a way as to show what the comp ny's pioneering in ceramic research means to the user of refractories.

"SIROCCO" FANS AND BLOWERS are described in bulletin No. 8001 recently issued by the American Blower Co. of Detroit, Mich. This bulletin is well illustrated with halftones and line drawings and contains a full set of tables giving the capacities, speeds, air velocities and other data convenient in selecting the proper type of fan for the service intended.

"ELECTRICAL PROTECTING MATERIALS and Conduit Fittings" is the title of catalog No. 31 recently issued by the Chicago Fuse Mfg. Co. of Chicago, Ill. This catalog illustrates, describes in detail and gives the list price of the various products manufactured by the Chicago Fuse Mfg. Co. and will be found of value to those contemplating wiring jobs, as well as those in maintenance work.